Spatial disparities in health center utilization in Huye District (Rwanda)

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Selbstständigkeitserklärung

Hiermit erkläre ich, die Dissertation selbstständig und nur unter Verwendung der angegebenen Hilfen und Hilfsmittel angefertigt zu haben.

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Abstract

Until now catchment areas of health centers are considered as the administrative boundaries of the sector where the health center is situated. The main objective of this study is to determine the actual catchment areas of health centers in Huye District (Southern Province, Rwanda) and to test approaches used in other studies in a geographical information system for an improved estimation of catchment areas. Furthermore reasons for disparities in health center utilization are to be revealed. Questionnaires filled with patients at health centers as well as data retrieved from registration books aim to give information about spatial disparities in health center utilization and serve as evaluation basis for further analysis.

The study shows that none of the tested methods is able to predict catchment areas or the population to be served in a satisfying accuracy. An own approach that combines different methods gives only second best results after Thiessen polygons regarding the served population while for none of the methods the boundaries match well the catchment areas as they are defined by the data.

Keywords: Medical Geography, Rwanda, Access of health care, Utilization of health centers

Zusammenfassung

Bisher wurden die Einzugsgebiete der Gesundheitszentren mit den administrativen Grenzen des Sektors, in dem das Gesundheitszentrum liegt, gleichgesetzt. Das Hauptanliegen dieser Arbeit ist es, die tatsächlichen Einzugsgebiete zu erfassen und bisher verwendete methodische Ansätze auf ihre Eignung zu testen, Einzugsgebiete für Gesundheitszentren möglichst realistisch zu modellieren. Darüber hinaus sollen Gründe für räumliche Unterschiede in der Inanspruchnahme von Gesundheitszentren ermittelt werden. Fragenbögen, die mit Patienten in den Gesundheitszentren ausgefüllt wurden, sowie aus Registrierungsbüchern erfasste Daten geben Aufschluss über die räumlichen Unterschiede bei der Inanspruchnahme und dienen als Referenzdaten für die weiteren Analysen.

Die Studie zeigt, dass keine der getesteten Methoden dazu geeignet ist, die Einzugsgebiete zufriedenstellend zu modellieren. Ein selbst entwickelter Ansatz, der verschiedene Methoden kombiniert, liefert bezüglich der Bevölkerung nur zweitbeste Ergebnisse nach Thiessen Polygonen während für keine der Methoden die Grenzen mit den Grenzen übereinstimmen, die für die tatsächliche Nutzung ermittelt wurden.

Schlagwörter: Medizinische Geographie, Ruanda, Zugang zu Gesundheitsversorgung, Inanspruchnahme von Gesundheitszentren

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Acronyms

2SFCA	Two-step floating catchment area (method)
CGIS	Center for Geographic Information Systems and Remote Sensing
CHUB	Centre Hospitalier Universitaire de Butare, University Teaching Hospital Butare
CHUK	Centre Hospitalier Universitaire de Kigali, University Teaching Hospital Kigali
CHW	Community Health Worker
C-IMCI	Community-based Integrated Management of Childhood Illnesses
CUSP	Centre Universitaire de Sante Publique
DEM	Digital Elevation Model
DHS	Demographic and Health Survey
DHSST	District Health System Strengthening Tool
DUI	Distance Utilization Index
ED	Euclidean distance
EDPRS	Economic Development and Poverty Reduction Strategy
FARG	Fonds National pour l'assistance aux Rescapés du Génocide
GIS	Geographical Information System
HC	Health center
HD	hors district, from outside the administratively responsible District
HMIS	Health Management Information System
HZ	hors zone, from outside the administratively assigned HC area Z
IDW	Inverse Distance Weighting
MDG	Millennium Development Goal
MINECOFIN	Ministry of Finance and Economic Planning
MMI	Military Medical Insurance
MOH	Ministry of Health
MSH	Management Sciences for Health
NGO	Non-governmental Organization
NLC	National Lands Center
NISR	National Institute of Statistics Rwanda
PBF	Performance-based Financing
PEPFAR	President's Emergency Plan for AIDS Relief

RAMA	Rwandaise d'Assurance Maladie
RD	Road distance
RNRA	Rwanda Natural Resources Authority
RWF	Rwandan francs
Sonarwa	Societé Nouvelle D'assurance du Rwanda
UN	United Nations
UNDP	United Nations Development Programme
USD	US-American Dollar
WHO	World Health Organization
Z	zone, from the administratively assigned area of a HC

Preface

The motivation for this thesis evolved from a project that was conducted in 2008, dealing with the spatial analysis of malaria. The main objective of the project based at the Malaria Unit of the Ministry of Health in cooperation with the National University of Rwanda was to develop a geographical information system for malaria in Rwanda. In context of this project the research team tried to estimate the catchment areas of health centers with a cost allocation analysis based on the topography, land use and road network (UEBERSCHÄR & IYIKIRENGA, 2009). Seeing the limitations of this approach, the idea of the present study emerged. Fortunately I found Prof. Dr. Elmar Kulke and Prof. Dr. Jürgen Schweikart as supervisors; I deeply thank them for their never ending support and their faith in me and my project. Additionally I have to thank Hypatia, the promoting program for female junior scientists at Beuth University Berlin, for their financial support during the (almost) final period of writing my thesis.

I want to thank the members of staff at the Ministry of Health in Rwanda, at the former Rwandan National Lands Center (now Rwanda Natural Resources Authority), at the National Institute of Statistics of Rwanda, at the Health Unit and the health centers in Huye District for their support with data and information. Also I need to express my thankfulness towards all the patients who were willing to participate in my survey.

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Nicole Ueberschär

April 2015

1 Introduction

It is often said that the access to primary health care services contributes to a better health status of a population (BLACK et al., 2004; GUAGLIARDO, 2004; LIU, 2007; MURAWSKI & CHURCH, 2009). But in fact, it is the utilization of health care services that affects mainly positively the health status (BUTSCH, 2011:54). The access to health care services enables patients to make use of them, and a better access increases the probability of utilization (KHAN & BHARDWAJ, 1994:67). This includes the spatial access as well as the accessibility by financial means and by social factors.

Among the efforts made to meet the targets of the health-related United Nations' Millennium Development Goals (MDGs)(UNITED NATIONS HEADQUARTERS, 2008a, 2008b, 2008c, 2008d), the access to health care is seen as a significant factor in effective health treatment for people in rural areas of developing countries (BLACK et al., 2004:1; MURAWSKI & CHURCH, 2009:102; STRASSER, 2003). Without an improved accessibility of health care services the targets are unlikely to be met (RUTHERFORD et al., 2010; TANSER, 2006:107).

With the Economic Development and Poverty Reduction Strategy (EDPRS) the Rwandan Government aims at the maximization of preventive health measures and the capacity building "for high quality and accessible health care services for the entire population" in order to meet the health-related MDGs (MINECOFIN, 2012, 2007; MOH, 2009:14). Although the infant mortality declined already significantly since 2005 from 86 per 1000 live births to 50 in 2010, to achieve the aim of 28 by 2015 is improbable. Also the under-5 mortality was reduced by 50 % during the same period. The implementation of the community-based integrated management of childhood illness (C-IMCI) in health facilities and communities as well as the introduction of new vaccines are seen as reasons for the decline (NISR et al., 2012:102f.). Nevertheless, the major causes for child mortality at hospitals in 2008 continued to be malaria, pulmonary infections, diarrhea and malnutrition (MOH, 2009:18); diseases that are easily preventable "through comprehensive and well-coordinated interventions" (UNDP, 2012). In 2010, in rural areas of Rwanda, only 45 % of those children suffering symptoms of acute respiratory infections sought treatment; from children with fever only 41 % were treated in rural areas. Another factor influencing the health seeking behavior is the wealth status: the poorest households are less likely to seek for advice or treatment when their children suffer severe symptoms (NISR et al., 2012:132).

While in 2010 98 % of women giving live birth reported to have been receiving antenatal care by a professional provider, still 33 % of the women in rural areas gave birth at home (only about 18 % in urban areas)(NISR et al., 2012:110/115ff.). These numbers underline the need for an improved geographical and financial access to health care which is also recognized by the Rwandan Ministry of Health (MOH, 2010a:1). Nevertheless, the health care system in Rwanda has steadily been improving during the last decade while the geographical and financial access to health services has already increased substantially (LOGIE et al., 2008; MOH, 2010a:xiii; MOH et al., 2009:4; NISR, 2006:4). In 2010, 77 % of the population could access a health facility within one hour walking travel time or in less than 5 km distance (MOH, 2010a:xvi), as recommended by the World Bank (THE WORLD BANK, 2001:339). The Ministry of Health still sees the need for improving the spatial access: In 2009/2010 it has spent almost 12 billion RWF (about 15 million Euro) for the budget item "geographical accessibility to health services" (MOH, 2010a:30).

All over the world and for many years, the access to health care in a broader view has been under investigation. The revealed barriers to accessing health care services can be grouped into spatial factors, like distance, lack of transport; financial factors, like costs of transport, informal costs, income, insurance status, occupational status; personal factors, like sex, age, race, ethnicity, psychological, informational, social, relationships; and organizational factors that can be assigned to health facilities, like low perceived quality of health care services, opening hours, waiting time (BASINGA et al., 2008; DONABEDIAN, 1972; FIEDLER, 1981; GESLER, 1986; GOINS et al., 2005; GRAVES, 2008; GULLIFORD et al., 2003; PARKHURST & SSENGOOBA, 2009; SUDHOF et al., 2013; TANSER et al., 2006). Until now, studies in Rwanda focused on financial aspects of access constraints but also on improving the services: A number of authors evaluated the impact on health care services of performance-based funding to primary health care providers (BASINGA et al., 2010, 2011; BASINGA et al., 2008; KALK et al., 2005; LOUIS RUSA et al, 2009; PAUL, 2009; RODRIGUEZ POSE & SAMUELS, 2011; SEKABARAGA et al., 2011). But also the high demand on health professionals has been a topic (BINAGWAHO et al., 2013). While a range of studies investigated on reducing financial barriers for health care utilization mainly by community-based health insurance schemes (DHILLON et al., 2012; KALK et al., 2005; KOHLER et al., 2012; RODRIGUEZ POSE & SAMUELS, 2011; SAKSENA et al., 2010, 2011; SCHMIDT et al., 2006; SCHNEIDER & DIOP, 2004; SCHNEIDER & HANSON, 2006; SEKABARAGA et al., 2011; WAKABI, 2007) only few studies have been dealing with the geographical access to health care in Rwanda until now (HUERTA MUNOZ & KÄLLESTÅL, 2012). Though this list is not

exhaustive it shows the fundamental need for further research regarding spatial and personal constraints to health care access and utilization.

1.1 Motivation

During a project conducted in Rwanda in 2008, the research team tried to estimate the catchment areas of health centers with a cost allocation analysis based on the topography, land use and road network, facing the lack of this information (UEBERSCHÄR & IYIKIRENGA, 2009). Confronted with the limitations of that approach, the question arose whether there might be a more precise way of modeling the catchment areas with help of a geographical information system. The need of evaluating the results of the modeling process raises also the question of access and utilization of health care in general and of health centers in particular.

Data provided by the Rwandan Ministry of Health shows that in 2008 up to 70 % of all patients were not coming from the catchment area assigned to the corresponding health center (MOH, 2010d). This might be due to the mere spatial distance. But looking at results of research done in other countries the awareness raises that there might be well-founded reasons why patients prefer a specific health center other than the closest one. PARKHURST & SSENGOOBA (2009:377) as well as AKIN & HUTCHINSON (1999:135) for example found patients by-passing the nearest health facility in order to reach a more popular one. Do these issues apply for Rwanda as well? Which impact do spatial, financial, personal or organizational factors have on the utilization on health care services in Rwanda? Though this thesis might not give answers to all aspects of these questions, it is conducted with the scope to contribute to the discussion of analyzing access and utilization in the context of the geographies of health. The comparison of different methods used in the GIS will add to a better understanding of their application. Additionally the thesis hopes to contribute to the general health care improvement process in Rwanda.

It should be noted that the focus of this study is on primary health care provision and utilization while primary health care in Rwanda can be compared to a level of care which, in 'Western' countries, is provided by community nurses and general practitioners (JOSEPH & PHILLIPS, 1984:1).

1.2 Objectives

The principal aim of this study is to develop a model that estimates most accurately catchment areas of health centers in Huye District, Rwanda. The study will identify the determining factors that influence the patients' decision in favor of a certain health center. With the help of GIS, the study will describe, analyze and explain the consequences with regard to their spatial effects.

Thus, the main research question that is leading this study is: How can catchment areas for health centers be modeled realistically with the help of GIS? For answering this question, parameters have to be identified that are taken into account for different modeling approaches. This includes considering the mode of travelling: How can walking distances be represented the best way in a model? And it includes finding possibilities of integrating the above mentioned factors for choosing a health center into the modelling process (see Figure 1.1).

This leads to the following objectives:

(1) To determine the actual catchment areas of health centers in the study area: Data from registration books is used to identify those villages from where patients come to use a health center. The catchment areas resulting from this data analysis are used to evaluate the different modeling approaches.

(2) To collect information about the means of transport mainly used by patients to reach the health center and the travel time: Questionnaires filled with patients at health centers aim to give this information.

(3) To determine the patients' reasons for consulting a specific health center: Information collected in context with the above mentioned questionnaires and through interviews with experts and group discussions contribute to an understanding of the utilization process.

(4) To test existing models and to develop an optimized model for an improved estimate of catchment areas: Different modeling approaches will be tested in respect of the specified factors/parameters. They are evaluated with help of the catchment areas defined by data analysis from registration books (see (1)) and through population data.

1.3 Structure of the thesis

This thesis aims to contribute to the understanding of spatial disparities in health center utilization in Huye District in Rwanda. This first chapter already introduced to the topic of accessibility of health in general and gave an overview of the study and the main objectives of this thesis. The next chapter (2) places the thematic background of this thesis in the context of medical geography and gives a review of findings related to the access to and the utilization of health care with a focus on the sub-Saharan region of Africa since this study is taking place in Rwanda (see Figure 1.1).

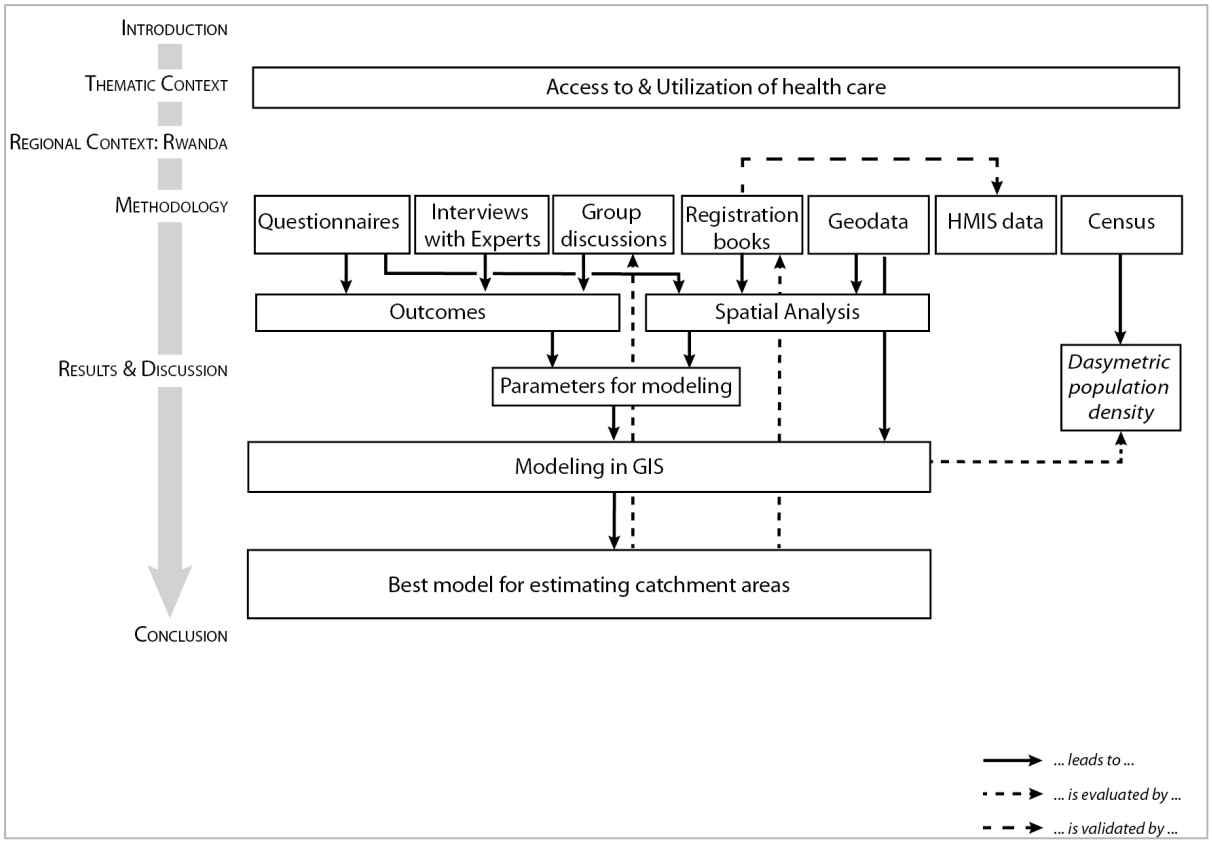

Figure 1.1: Overview of the thesis

This leads to the next chapter (3) where the regional context of Rwanda is put to focus. Different aspects explain the conditions that need to be considered for analyzing the access to and the utilization of health care in Rwanda. The forth chapter gives an overview of the study design and the study area. It explains in detail the data used for the study and the different approaches tested for modeling catchment areas. The results of the survey and of the different modeling approaches are presented and discussed in chapter 5. The last chapter (6) summarizes the findings and gives a conclusion. It is completed by suggestions for further research.

2 Thematic context

The following theoretical concepts will serve to ground the topic of this thesis within the context of current research. It gives a short overview about the embedding of health care geography within the geographies of health before looking in detail at different approaches for analyzing the access to and the utilization of health care. Barriers to utilization are summarized from previous studies. This second part is concluded by introducing the framework of the here presented study. The third part of this chapter gives insight in the application of geographical information systems on problems related to the access to and the utilization of health care services.

2.1 Geographies of health

The importance of analyzing health concerns in connection to the environment has been realized already 2000 years ago. At this time, the research field of disease ecology was founded with the first studies to existing spatial disparities of environmental conditions and lifestyle habits in correlation to variations in human health and well-being (GREGORY et al., 2009:451; KISTEMANN & SCHWEIKART, 2010:4; MEADE & EARICKSON, 2000). In the 18th and 19th century, the German medical doctors Finke, Fuchs and Hirsch influenced the terminology of medical geography. At the same time, the British doctor Snow discovered the connection between the spread of cholera and the utilization of a water pump in London and the German geographer Petermann mapped the cholera epidemics in England. This is seen as an important starting point for an ongoing interdisciplinary partnership of geography and medicine, although the main roots are much older (KISTEMANN et al., 1997:198; BUTSCH, 2011:20ff.). BARRETT (2000) has written in detail about the origin and the development of the relationship between geography and medicine (see also EARICKSON, 2009:10; VALENČIUS, 2000), while BUTSCH (2011:21ff.) and KISTEMANN et al. (KISTEMANN et al., 2002; KISTEMANN et al., 1997; KISTEMANN & SCHWEIKART, 2010) give an overview of the development of medical geography in German speaking countries where it is quite an exotic sub-discipline of human geography (BUTSCH, 2011:22). More recently the activities and publications of the French medical doctor Jacques May (e.g. MAY, 1950) attracted again the attention on disease ecology and linked it to the domain of geography (KISTEMANN & SCHWEIKART, 2010:5). In English speaking countries the term medical geography involves a wider field of research than it does in German

speaking countries and it has stronger connections to institutions (BUTSCH, 2011:23). For a more detailed introduction to medical geography see e.g. EARICKSON, 2009; MEADE & EARICKSON, 2000; MEADE & EMCH, 2010; PHILO, 2009.

While in the 1990s, medical geography was still one of the minor subfields of geography, since then it is also one of the most rapidly growing sub disciplines of geography (MAYER, 1990:175). For a long time researchers are discussing about contents, methods and theoretical concepts of medical geography (BENNETT, 2005; BROWN et al., 2010; BUTSCH, 2011:23; KEARNS & MOON, 2002; MAY, 1977; ROSENBERG, 1998). “In adapting the discourses about the role of social theory and the cultural turn in human geography, medical geography re-invented itself as the geography of health” (KEARNS & GESLER, 1998:3; KISTEMANN & SCHWEIKART, 2010:10). The terms “geographies of health” or “health geography” are now also used for “describing the encounter between geography and death, disease, and related aspects of service provision“ (KEARNS & GESLER, 1998; MOON, 2009:35), although there is still a wish to keep the old term “medical geography” (BUTSCH, 2011:23). While health geography aims to use more qualitative methods and includes in the terminology of ”disease” also social and biological factors, medical geography focuses on the medical understanding of disease, using more quantitative methods. No matter if it is called medical geography or health geography (or geographies of health) – two key aspects evolved over the years: disease ecology, also called geographical epidemiology or geographic pathology (MAYER, 1982), and healthcare geography (KISTEMANN et al., 1997). Disease ecology describes “spatial patterns of morbidity and mortality” including the diffusion and etiology of diseases (GESLER, 1986). Studies in this field deal for example with the spatio-seasonal modeling of malaria incidence rates (ABELLANA et al., 2008; YESHIWONDIM et al., 2009); transmission patterns of tuberculosis (MUNCH et al., 2003); or diarrhea prevalence (PANDE et al., 2008). In this context methods based on geographical information systems (GIS) and remote sensing have been increasing over the last decades especially with regard to the analysis of vector-borne diseases like malaria (CECCATO, 2006; DAMBACH et al., 2012; PARKER & CAMPBELL, 1998; RAHMAN et al., 2010; SITHIPRASASNA et al., 2005; THOMSON et al., 1997; TRAN et al., 2008) and dengue fever (ARBOLEDA et al., 2009; CHANG et al., 2009; HERNÁNDEZ-ÁVILA et al., 2013) or schistosomiasis (SCHUR et al., 2011; SIMOONGA et al., 2009; SOUZA GOMES et al., 2012) as well as tuberculosis (BEYERS et al., 1996).

Healthcare geography found its way into health geography in context with the higher linkage to institutions in English speaking countries (KISTEMANN & SCHWEIKART, 2010), especially in Great Britain, USA and Canada. It "is concerned with: (1) how places differ in terms of the needs and demands for healthcare, (2) cultural, political, and economic circumstances that affect how much care is actually needed and used, (3) inequities in the provision of care, and (4) methods and models that address spatial inequities and offer spatial solutions" (EARICKSON, 2009:16f.; see also BIRKIN et al., 1996; BUTSCH, 2011:23; GESLER, 1986; GREGORY et al., 2009:452; JOSEPH & PHILLIPS, 1984; MAYER, 1982). EARICKSON adds the field of malnutrition, as a "factor in sickness and health" (EARICKSON, 2009:9). The utilization of qualitative methods enables health geographers to include more and more "human expressions of their health status and needs" instead of focusing only on data collection and their presentation in maps (EARICKSON, 2009:19). This plays for example in context with the health-seeking behavior of a target population an important role (ABRAHAMS et al., 2001) but also for including perceived barriers to health care access (BAKEERA et al., 2009; GOINS et al., 2005; GOUDGE et al., 2009; PARKHURST et al., 2006) or for studying the motivation of health related staff in context to performance based payments (PAUL, 2009).

2.2 Access and utilization

2.2.1 Access

The above cited concerns of healthcare geography include in all categories the access to and the utilization of health care as two important geographical perspectives on health care provision (JOSEPH & PHILLIPS, 1984:9). Both influence mainly positively the health status of a population (BUTSCH, 2011:54; CSDH, 2008). Despite the widely accepted importance of access to health care for determining health issues and as an indicator for health system evaluation this access is often not well and not equally defined (ADAY & ANDERSEN, 1974; BUTSCH, 2011; KHAN & BHARDWAJ, 1994; PENCHANSKY & THOMAS, 1981). Some authors equate access with the entry into the health care system or the utilization of it (FOX, 1972; PENCHANSKY & THOMAS, 1981; SALKEVER, 1975); some equate access with attributes of the potential user or the community or of the health care delivery system (KHAN & BHARDWAJ, 1994). Others suggest to evaluate access through indicators like satisfaction scores or utilization rates (ADAY & ANDERSEN, 1974:209). PENCHANSKY & THOMAS (1981) point out that "the problem is not limited to the lack of a precise definition for access, or the multiple meanings

given to the term; access also is used synonymously with such terms as accessible and available, which are themselves ill-defined" (PENCHANSKY & THOMAS, 1981:127). They summarize that "[…] access is most frequently viewed as a concept that somehow relates to consumers' ability or willingness to enter into the health care system" (PENCHANSKY & THOMAS, 1981:128).

Two basic frameworks are presented here that have been found helpful for the research related to the access to health care and have been further improved over the years: ADAY & ANDERSEN (1974); and PENCHANSKY & THOMAS (1981); plus some developments based on these approaches.

2.2.1.1 Aday and Andersen's framework for the study of access

ADAY & ANDERSEN (1974:211f.) define their "basic framework for the study of access", as a process "from health policy objectives through the characteristics of the health care system and of the populations at risk (inputs) to the outcomes or outputs: actual utilization of health care services and consumer satisfaction with these services" (ADAY & ANDERSEN, 1974:211f.; see Figure 2.1). They suggest to use two main categories of indicators to validate the access to health care: process and outcome indicators. In this context, process indicators could be for example on side of the health delivery system: physician/population ratios per areal unit, mean travel time, working hours; on side of the population: knowledge and sources of health care information, insurance coverage, residential mobility, symptoms of illness. Outcome indicators could be measures of utilization or consumer satisfaction (ADAY & ANDERSEN, 1974:216f.). The framework's indicators correspond to the structure, process, and outcome measures suggested by DONABEDIAN (1972) for evaluating the quality of medical care (DONABEDIAN, 1972; KHAN & BHARDWAJ, 1994:65). ADAY & ANDERSEN are developing a research framework for the study of access but they fail to give a clear definition what access to health care exactly means. Still, the suggested indicators can be helpful for evaluating a health care system. And "it recognizes that access involves more than the mere existence or availability of resources at a given time" (ADAY & ANDERSEN, 1974:209f.; JOSEPH & PHILLIPS, 1984:114f.).

Based on ADAY & ANDERSEN's framework, ADAY, ANDERSEN & FLEMING (ADAY et al., 1980) define access "as those dimensions which describe the potential and actual entry of a given population group to the health care delivery system" (ADAY et al., 1980; cited in KHAN &

BHARDWAJ, 1994; see also ANDERSEN & ADAY, 1978). JOSEPH & PHILLIPS (1984) prefer the terms potential and revealed accessibility. KHAN (1992) readopts this dichotomy of potential and actual/realized access and draws a 2 x 2 matrix of two sets of dichotomies: the potential/realized access and – based on the barrier-related approach of LEWIS (1977) – the spatial/aspatial access which is extended by the dimensions organization and costs by KHAN & BHARDWAJ (1994). GUAGLIARDO (2004) puts it closer to the actual health care provision, defining access to healthcare by introducing the two broad stages of "potential" for care delivery and the "realized" delivery of health care.

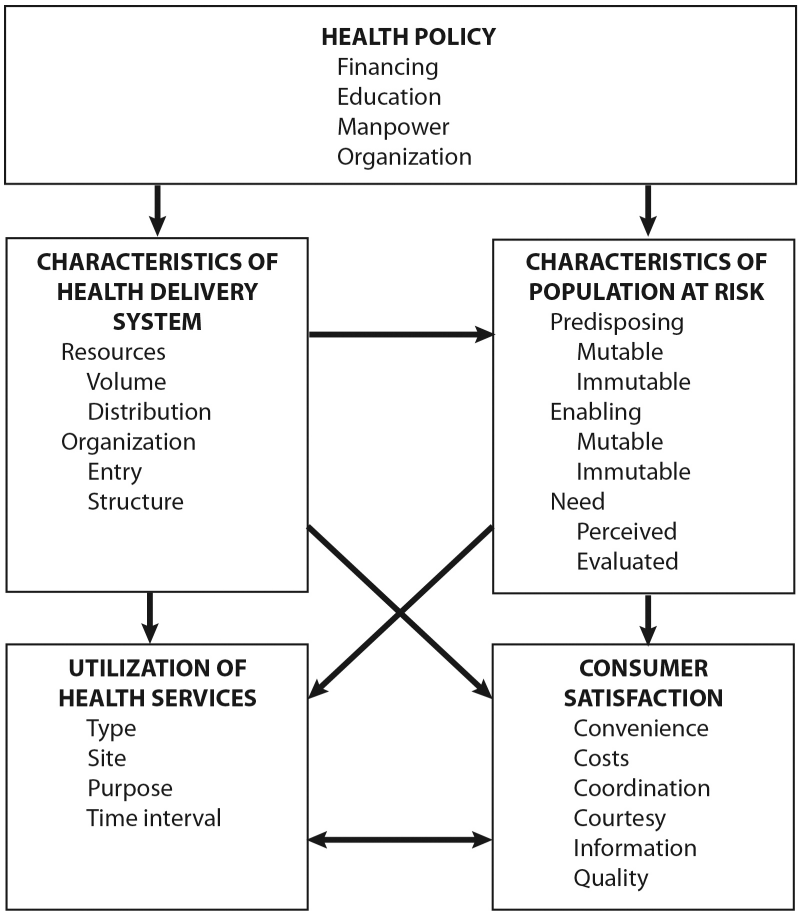

Figure 2.1: Framework for the study of access (own design after ADAY & ANDERSEN, 1974:212)

2.2.1.2 Penchansky and Thomas' dimensions of access

PENCHANSKY & THOMAS (1981) define access "as a concept representing the degree of 'fit' between the clients and the system" (PENCHANSKY & THOMAS, 1981:128). They relate their "concept of access" to the enabling variables of the behavioral model developed by ANDERSEN in the 1960s (ANDERSEN, 1968). The model specifies predisposing characteristics, enabling resources (related to the person/family and to the community), the need and the use of

health services (ANDERSEN, 1968, 1995). PENCHANSKY & THOMAS' (1981) concept summarizes the dimensions of access as:

> *"**Availability**, the relationship of the volume and type of existing services (and resources) to the clients' volume and types of needs. It refers to the adequacy of the supply of physicians, dentists and other providers; of facilities such as clinics and hospitals; and of specialized programs and services such as mental health and emergency care.*
>
> ***Accessibility**, the relationship between the location of supply and the location of clients, taking account of client transportation resources and travel time, distance and cost.*
>
> ***Accommodation**, the relationship between the manner in which the supply resources are organized to accept clients (including appointment systems, hours of operation, walk-in facilities, telephone services) and the clients' ability to accommodate to these factors and the clients' perception of their appropriateness.*
>
> ***Affordability**, the relationship of prices of services and providers' insurance or deposit requirements to the clients' income, ability to pay, and existing health insurance. Client perception of worth relative to total cost is a concern here, as is clients' knowledge of prices, total cost and possible credit arrangements.*
>
> ***Acceptability**, the relationship of clients' attitudes about personal and practice characteristics of providers to the actual characteristics of existing providers, as well as to provider attitudes about acceptable personal characteristics of clients. In the literature, the term appears to be used most often to refer to specific consumer reaction to such provider attributes as age, sex, ethnicity, type of facility, neighborhood of facility, or religious affiliation of facility or provider. In turn, providers have attitudes about the preferred attributes of clients or their financing mechanisms. Providers either may be unwilling to serve certain types of clients (e.g., welfare patients) or, through accommodation, make themselves more or less available." (PENCHANSKY & THOMAS, 1981:128f.)*

Even though the authors admit that those dimensions are not easily distinguished they don't explain the nature and levels of interaction between them (BUTSCH, 2011; KHAN & BHARDWAJ, 1994:63). Furthermore, the authors disregard the close relationship of access with the ability to receive needed services and the barriers that influence the utilization (KHAN & BHARDWAJ, 1994:63). Still, the dimensions allow researchers to evaluate the access to health care from different perspectives and give ideas of possible constraints.

Although they do not explicitly name the concept of access by PENCHANSKY & THOMAS, OBRIST et al. (2007) apply the five dimensions to their framework for analyzing and improving access to health care in the context of "resource-poor countries" (OBRIST et al., 2007:1584). They build their framework on three perspectives for investigating health care access: health-seeking studies which focus on people (e.g. MACKIAN et al., 2004; SHAIKH & HATCHER, 2005; VAN DER HOEVEN et al., 2012); health service studies which concentrate on access to

health care and the factors that affect it (e.g. ANDERSEN, 1995; BAKEERA et al., 2009; GAGE, 2007), focusing on the supply side (see ENSOR & COOPER, 2004; GULLIFORD et al., 2002); livelihood approaches which "emphasize assets […] and activities needed to gain and sustain a living under conditions of economic hardship" (OBRIST et al., 2007:1585; e.g. CHAMBERS, 1995; HAAN & ZOOMERS, 2005). The Health Access Livelihood Framework puts the access to health care in the context of livelihood insecurity while combining health service and health-seeking approaches (OBRIST et al., 2007:1585). The framework considers five dimensions of access: Availability, Accessibility, Affordability, Adequacy, and Acceptability. They remind of those introduced by PENCHANSKY & THOMAS (1981) only that OBRIST and colleagues have exchanged the "Accommodation" by "Adequacy" although the authors obviously mean the same. In fact, the term adequacy does not match well the affiliated questions by OBRIST et al. but is included in their dimension of availability as well as how it is described by PENCHANSKY & THOMAS (1981). OBRIST et al. (2007) themselves do not seem to be very clear about the difference between adequacy and acceptability in their approach; they relate it both to the "people's judgment of quality of care" (OBRIST et al., 2007:1585). BUTSCH (2011) criticizes the approach of OBRIST and her colleagues for not including preventive health care because they relate access only to the recognition of illness and the initiation of a treatment seeking progress (OBRIST et al., 2007:1585). Nevertheless, it helps to apply the access dimensions developed for the United States of America on the resource-poor countries (e.g. BALEN et al., 2013).

BUTSCH (2011) defines access to health care services as the opportunity to utilize suitable preventive, curative and custodial health care services (BUTSCH, 2011:77). He points out that access cannot be equalized neither alone with actual utilization nor with the potential access. He emphasizes the need of curative health care utilization for improving the health status but also the need of preventive health care utilization for maintaining the (good) health status. Finally, he is including the evaluation of the quality of health care ("suitable" – in German "adäquat") in his definition of access. BUTSCH builds his framework mainly on the approach by PENCHANSKY & THOMAS (1981) although he criticizes that the actual utilization process is not included in their definition of access or that it is reduced to an indicator. He defines then the actual access (utilization) by realized access opportunities that are influenced by six dimensions. Here BUTSCH uses the five dimensions of access (availability, accessibility, accommodation, affordability, acceptability) by PENCHANSKY & THOMAS (1981:128f.) plus the dimension of awareness ("Informiertheit"; BUTSCH, 2011:78). He furthermore defines adequate access as the utilization of curative, preventive and custodial

services and their sufficient qualitative level. Into his framework for analyzing the access to health care services he furthermore includes barriers and facilitators for each dimension (see LEWIS, 1977; cited in KHAN & BHARDWAJ, 1994). Utilization occurs when the facilitators overwhelm the barriers (BUTSCH, 2011:78; see also KHAN, 1992:275f.).

PETERS and his colleagues (PETERS et al., 2008) base their approach on ADAY & ANDERSEN's (1974) framework as well as on PENCHANSKY & THOMAS's (1981) idea of the 5 As for access:

> ***"1. Geographic accessibility**—the physical distance or travel time from service delivery point to the user*
>
> ***2. Availability**—having the right type of care available to those who need it, such as hours of operation and waiting times that meet demands of those who would use care, as well as having the appropriate type of service providers and materials*
>
> ***3. Financial accessibility**—the relationship between the price of services (in part affected by their costs) and the willingness and ability of users to pay for those services, as well as be protected from the economic consequences of health costs*
>
> ***4. Acceptability**—the match between how responsive health service providers are to the social and cultural expectations of individual users and communities" (PETERS et al., 2008:162).*

They put the quality of health care in the center of their approach because they see it as a main component of each dimension and that it "is ultimately related to the technical ability of health services to affect people's health" (PETERS et al., 2008:162).

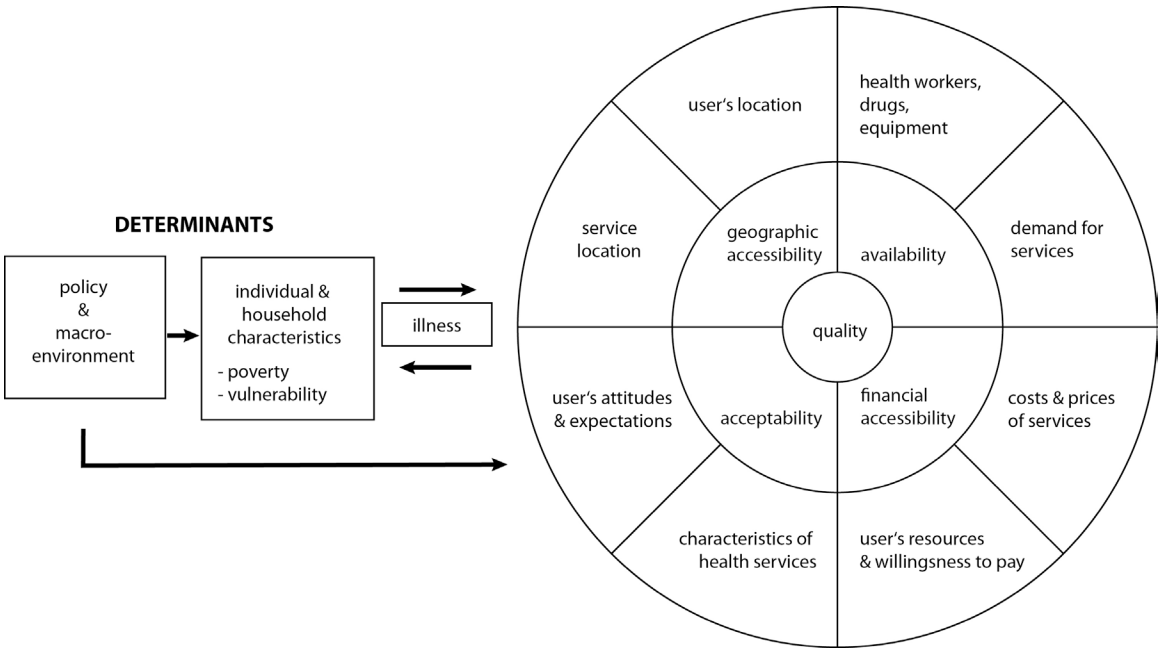

Figure 2.2: PETERS' ET AL. framework for assessing the access to health care services (own design after PETERS et al., 2008:162)

Although the terms access and accessibility are often used synonymously in the context of access and accessibility to health care, it is worth noticing the small difference. While ***access*** is the "ability, right or permission to approach, enter […] or use" a health care service (DICTIONARY.COM), ***accessibility*** is defined as "the ease with which people can reach desired activity sites" (HANSON, 2009:2). Thus access is the potential of making use of a health care service while accessibility describes the effort of actually using it. ***Spatial access*** can be equalized with "availability", meaning the mere existence of health care services in an area, measuring the number of available health centers in a specified distance for example. In contrast, the spatial/geographic/***physical accessibility*** takes into account spatial barriers – e.g. the topography, the availability of public transport, the road network, distance between patient and health service – to specify the ease (or the difficulties) for the utilization of health care services. Accordingly, ***financial accessibility*** considers financial barriers like consultation fees, costs for transport, loss of income, etc. while seeking for health care.

2.2.2 Spatial access and spatial accessibility

Spatial access can be interpreted as the regional availability of services (JOSEPH & PHILLIPS, 1984; KHAN, 1992). Although it is only one indicator to assess the spatial accessibility, distance is often taken as a proxy variable for measuring the access to health care services (ALBERT et al., 2000; HEARD et al., 2004) and their utilization (TANSER, 2006:110f.). BUOR (2003) gives reasonable examples why distance alone is not a good measure for accessibility. He suggests to relate the role of distance to the travel time and transport costs. Still, distance to health facilities is one of the indicators that also the WHO and the World Bank uses to assess the access to health care, specified by the population living within one hour by local transport means to the next health center (THE WORLD BANK, 2005:338). In the context of sub-Saharan Africa this "one-hour rule" is interpreted as 5 km walking distance and used as a benchmark (BASINGA et al., 2008:94; MOH, 2010a; NOOR et al., 2004; NOOR et al., 2009; TSOKA & LE SUEUR, 2004; see also section 2.3). To assess and to improve the physical accessibility of health facilities is a major concern of many developing countries in order to meet the health related MDGs (HUERTA MUNOZ & KÄLLESTÅL, 2012; HUYE DISTRICT, 2007; MOH, 2010a; NOOR et al., 2006; PERRY & GESLER, 2000; TANSER, 2006:107).

OPPONG & HODGSON (1994) showed that the geographical accessibility of health facilities in rural Ghana can be improved despite limited resources with better locational choices and without additional facilities. In fact, even a smaller number of health facilities could serve

the area with remaining the accessibility rate if they would be placed more efficiently. The same found already AYENI et al. (1987) for rural areas in Nigeria to be applicable. While the spatial accessibility has been improved over ten years by establishing new health facilities, it could have been improved even more if the new facilities would have been placed in better locations (AYENI et al., 1987).

BLANFORD et al. (2012) investigated on the physical access of the population of six districts in Niger to health facilities, emphasizing on seasonal conditions and their effects on the availability of adequate health care. For the dry season they found only 39 % of the population living within a 1-hours walk to a health facility, even only 24 % during the rainy season. Also they found a high correlation of vaccination rates for children with proximity to a health facility, similar to findings of SCHWEIKART (1992) in Cameroon who examined a high decline of vaccinations with an increased travel distance to the clinic (SCHWEIKART, 1992; BLANFORD et al., 2012).

HUERTA MUNOZ & KÄLLESTÅL (2012) used three different scenarios to estimate the population within an one hour travel distance from the nearest primary health facility in the Western Province of Rwanda. As could have been expected, the use of a bicycle in combination with walking, greatly increases the population within the specified travel distance. Due to the lack of public transport, a combination of walking and use of public transport is resulting in a smaller number of served population. The one hour walking distance gives the lowest results (26.6 % of the population).

NOOR and colleagues (2004) measured the distances between centroids of sub-locations and the closest health center. In their study area in Kenya they found 82 % of the population living within a distance of 5 km or less to the next public health facility.

2.2.3 Utilization

While one indicator for the performance of a health system is the service provision (availability), the actual utilization of services might be even more important to be assessed. Many studies have shown the relevance of distance in context to utilization, showing that utilization decreases with an increase of distance to a health facility (BARNETT & BARNETT, 2009:67; BIRKIN et al., 1996). But even with an optimal distribution of health care providers in an area, utilization may take place or not (JOSEPH & PHILLIPS, 1984:111). Utilization of services means the realized access to health care. And assessing the access to health care should

consider whether people who need care make use of it (ADAY & ANDERSEN, 1974; DONABEDIAN, 1972; JOSEPH & PHILLIPS, 1984). FIEDLER (1981; based on MECHANIC, 1972 and ROSEN ET AL., 1975) specifies four requirements for utilization that come close to the dimensions of access identified by PENCHANSKY & THOMAS (1981): The awareness of the patient of his condition and the perceived need to change it; the availability of an appropriate health service within an acceptable distance; the acceptability on side of the patient of the offered service; and the ability to make use of the service in terms of financial means and the time needed. Each of the four requirements comprises potential barriers and positive factors influencing the utilization of health care (FIEDLER, 1981:129; JOSEPH & PHILLIPS, 1984:2). Promoting variables can be for example age, sex, mobility, income, or knowledge; hindering variables can be lack of income or mobility (JOSEPH & PHILLIPS, 1984:2). But utilization can only be achieved when facilitators outweigh the barriers (KHAN, 1992). ANNIS (1981:515) points out that it is more important to improve the quality of health care services instead of building new health facilities in order to improve levels of utilization.

During the last decades the access to and the utilization of health care services has been under investigation especially for rural areas of the U.S.A. (ANDERSEN & NEWMAN, 1973; BUCHANAN et al., 2006; FIEDLER, 1981; GOINS et al., 2005; GULLIFORD, 2002; HICKS, 1990; MCGUIRK & PORELL, 1984; MOBLEY et al., 2006; SLIFKIN, 2002), Great Britain (BIRKIN et al., 1996; ENSOR & COOPER, 2004; FIELD & BRIGGS, 2001; MOONEY, 1983; PARKER & CAMPBELL, 1998; STRONG et al., 2007), and Canada (CINNAMON et al., 2008; SCHUURMAN et al., 2010). Also studies about the spatial accessibility of health care services in sub-Saharan Africa are increasing (see below). In terms of monitoring indicators of utilization two streams can be found: while one concentrates on utilization patterns the second focuses on potential barriers to utilization (JOSEPH & PHILLIPS, 1984:58f.). For both areas, research has been limited until now for the African context. A number of studies investigated on people living with HIV (BOGART et al., 2013; GOUDGE et al., 2009; WILLIAMS, 2014) and maternal health issues (AYENI et al., 1987; BYFORD-RICHARDSON et al., 2013; FEINSTEIN et al., 2013; GAGE, 2007; KYOMUHENDO, 2003; PARKHURST et al., 2006; PARKHURST & SSENGOOBA, 2009; TEY & LAI, 2013) in combination with barriers to the utilization of health care services. Still, studies for sub-Saharan Africa on the utilization of primary health care as a curative and preventive health care service remain limited.

GOUDGE et al. (2009) for example was focusing on the chronically ill while investigating on affordability, availability and acceptability barriers to health care in South Africa. Especially for the chronically ill the financial burden is often high but also the lack of drug supplies, insufficient clinic services, or lack of ambulances hampers the access to health care services. The authors found that also poor provider-patient interaction can be a reason for an ineffective utilization of the public health system (GOUDGE et al., 2009).

Although the main objective of the study by NOOR and his colleagues (NOOR et al., 2006) was to evaluate the spatial access to medical treatment in Kenya they also had a closer look on use of government health services by febrile children. They found higher-order facilities to be more attractive for patients than lower-order ones. Although their developed model estimates the served population with 10 % more predictive power than previous approaches, they admit that the model needs to be adjusted for socio-economic determinants of access to health care (NOOR et al., 2006).

Already in 2003 NOOR investigated with some other colleagues (NOOR et al., 2003) mainly on the spatial accessibility of public health facilities in Kenya. They compared the theoretical physical access to the actual health service usage which were highly correlated. Still they found patients not attending the nearest health facility but instead using one in a higher distance, “indicating that there might be other non-distance factors, such as perceived quality of services, which determined the use of health facilities” (NOOR et al., 2003:924).

Also the study of TANSER and his colleagues (TANSER et al., 2006) focuses more on the spatial dimension of access to health care in a health sub-district of South Africa. For the development of their model for estimating catchment areas they took into account reported travel times and the proportion of the population presumably using public transport. Their model predicts with an accuracy of 91 % the correct clinic. They found in general people using the closest (in terms of travel time) clinic but also found one clinic to be substantially less attractive and underutilized compared to expectations. On the other hand they found an overutilization relative to expectations for a clinic close to two main roads. In a previous study TANSER and his colleagues found the proximity to mini bus routes to be a possible reason for the utilization of a clinic by a large number of patients coming from another clinic’s catchment area (TANSER et al., 2001).

One problem of analyzing the utilization of health care is, that the identification of utilization pattern does not automatically reveal the relative importance of the various barriers or facilitators of geographical, socio-economic, and organizational nature that lay between need and utilization (FIEDLER, 1981).

2.2.4 Barriers to the utilization of health care services

"If, for any reason, the population does not use a service, that reason becomes a barrier to the attainment of good health" (AYENI et al., 1987:1083). For each of the dimensions of access, barriers and facilitators can be found. LEWIS (1977) assigns them to the consumption and the production side of services which is comparable to KIWANUKA and colleagues' (2008) classification in barriers on the consumer's and the service provider's side. AYENI et al. (1987:1083) summarizes them to institutional and geographical barriers: "Institutional barriers may refer to inability to pay, discriminatory practices, legal restrictions, social barriers, or perception of the quality of service. If the reason is 'long distances to service', then the problem is one of geographical accessibility. If it is to be overcome, the distances must be made shorter by locating or changing the locations of the service. If other circumstances prevent the population from using the service at the given distance, they should be changed so that people will be willing to 'go the extra mile'" (AYENI et al., 1987:1083).

The following table (Table 2.1) gives an overview of possible barriers and facilitators for utilization of health care that are mentioned in the literature. They are grouped according to the five dimensions of access established by PENCHANSKY & THOMAS (1981) and the additional dimension of awareness ("Informiertheit") introduced by BUTSCH (2011). Some barriers/facilitators appear for different dimensions depending on the cited author's opinion. Despite the affiliation to a dimension of access it should be noted that most of the barriers/facilitators do not appear separately but in close relationship or in dependency to another factor. For example, the availability of public transport has an higher impact on long distances while the costs for public transport do not apply in regions where it is not available. If the costs for the needed health service are too high the proximity to the health facility most probably does not overcome the financial barrier. Accordingly, LEWIS (1977) counts the economic or financial barriers to the most important factors on the consumption side.

Table 2.1: Dimensions of access and affiliated barriers and facilitators

Dimension of Access	Barrier	Facilitator
Availability	(perceived) lack of drug stocks (BAKEERA et al., 2009; GOUDGE et al., 2009; PETERS et al., 2008; AMER, 2007) limited opening hours (PETERS et al., 2008) dearth of health facilities (GAGE, 2007) lack of ambulances (GOUDGE et al., 2009)	high number of facilities and offered services (BUTSCH, 2011) opening hours (PETERS et al., 2008) adequate supply in relation to need (BUTSCH, 2011; OBRIST et al., 2007; PENCHANSKY & THOMAS, 1981) availability of drugs (KIWANUKA et al., 2008; OBRIST et al., 2007)
(Geographic) Accessibility	costs for public transport (BUTSCH, 2011; PENCHANSKY & THOMAS, 1981) long distance, travel time (BUTSCH, 2011; PENCHANSKY & THOMAS, 1981; PETERS et al., 2008) long distance, lack of public transport, lack of private means of transport (OBRIST et al., 2007) distance, transportation problems (GAGE, 2007; PARKHURST & SSENGOOBA, 2009) lack of public transport, terrain-related problems, long travel distances (BUCHANAN et al., 2006:361) cost, distance (TEY & LAI, 2013)	short distance to services (BAKEERA et al., 2009; KIWANUKA et al., 2008) good roads (PETERS et al., 2008) transportation resources (BAKEERA et al., 2009; PENCHANSKY & THOMAS, 1981) proximity to tarmac roads (BAKEERA et al., 2009) perceived security of the area (BAKEERA et al., 2009) place of residence (TEY & LAI, 2013)
Accommodation/ Adequacy	limited opening hours, long waiting time (BAKEERA et al., 2009; BUTSCH, 2011) limitations through health insurance (BUTSCH, 2011) insufficient clinical services (GOUDGE et al., 2009) long waiting time (AMER, 2007)	opening hours (24/7)(BUTSCH, 2011; PENCHANSKY & THOMAS, 1981) perceived appropriateness (PENCHANSKY & THOMAS, 1981) perceived quality of care (KIWANUKA et al., 2008; OBRIST et al., 2007)
Affordability/ Financial accessibility	costs for health services (BUTSCH, 2011; KIWANUKA et al., 2008; MAMDANI & BANGSER, 2004; RUTHERFORD et al., 2010) informal and indirect costs (ABEL-SMITH & RAWAL, 1992; PETERS et al., 2008) direct and indirect costs (OBRIST et al., 2007) costs (BAKEERA et al., 2009; BASINGA et al., 2008:104; PARKHURST & SSENGOOBA, 2009) informal costs (BAKEERA et al., 2009; MAMDANI & BANGSER, 2004) hidden costs (ABEL-SMITH & RAWAL, 1992) repeated costs (GOUDGE et al., 2009)	community health insurance (BUTSCH, 2011) reducing/waiving fees for health services (BUTSCH, 2011) knowledge of prices, total cost and possible credit arrangements (PENCHANSKY & THOMAS, 1981) income source (BAKEERA et al., 2009) free services (BAKEERA et al., 2009; RUTHERFORD et al., 2010) family wealth (TEY & LAI, 2013)

Dimension of Access	Barrier	Facilitator
Acceptability	socio-cultural factors: social affiliation, relationship to supplier, recommendations, prejudices, high utilization (BUTSCH, 2011) perceived low quality (BAKEERA et al., 2009; PARKHURST & SSENGOOBA, 2009; PETERS et al., 2008; AMER, 2007) gender inequities (BAKEERA et al., 2009; PETERS et al., 2008) social/personal characteristics of the provider and of the patients (PENCHANSKY & THOMAS, 1981) socio-cultural norms against the use of services (PARKHURST & SSENGOOBA, 2009) perceived bad attitude in health care providers against the patient (BAKEERA et al., 2009; KIWANUKA et al., 2008; AMER, 2007) lack of trust in the usefulness of certain interventions (BAKEERA et al., 2009) lack of trust in the qualification of health workers (BAKEERA et al., 2009; KIWANUKA et al., 2008) fear of stigma or discrimination (BOGART et al., 2013; RISHER et al., 2013) poor provider-patient interaction (GOUDGE et al., 2009) lack of family support, cultural isolation, workload constraints (RUTHERFORD et al., 2010) not perceived need for health care services, objections from husband and family (TEY & LAI, 2013)	socio-cultural factors: social affiliation, relationship to supplier, recommendations)(BUTSCH, 2011) social resources (BAKEERA et al., 2009) female autonomy (RUTHERFORD et al., 2010)
Awareness, Knowledge (Informiertheit) (BUTSCH, 2011)	lack of (health) knowledge (see also KIWANUKA et al., 2008; RUTHERFORD et al., 2010)	awareness of need for health care; knowledge about available suppliers; health monitoring of the health status of the population and for assessing the demand for health care (see also (ADAY & ANDERSEN, 1974; BAKEERA et al., 2009; ELNICKI et al., 1995; JOSEPH & PHILLIPS, 1984) health literacy (BAKEERA et al., 2009) proximity to people with secondary or higher education (GAGE, 2007) educational level, (women's) media exposure status (TEY & LAI, 2013)

Please note: findings of RUTHERFORD et al. (2010), BUCHANAN et al. (2006:361), PETERS et al. (2008) and PARKHURST & SSENGOOBA (2009) are cited from other papers' results.

While by the introduction of community health insurances the direct costs can be minimized and thus utilization improved (COMFORT et al., 2013; DHILLON et al., 2012; LOGIE et al., 2008; SEKABARAGA et al., 2011), still the informal and indirect/hidden costs affect especially the poor (ABEL-SMITH & RAWAL, 1992; MAMDANI & BANGSER, 2004). Indirect or hidden costs can be for example the inadequate supply of drugs resulting in the need of more drugs than normally necessary or the need for food at the hospital. Also the need for regular visits by the family to take care of an inpatient family member can result in higher costs for public transport or the loss of income. Informal costs mean for example the payment of bribes which still seems to be common in African countries (ABEL-SMITH & RAWAL, 1992; BAKEERA et al., 2009; KYOMUHENDO, 2003; MAMDANI & BANGSER, 2004; AMER, 2007).

2.2.5 Framework for the here presented study

In this study the patient, the environment and the health centers are included into the research (see Figure 2.3, see also section 4.2). For spatial analysis the location of the user of the health care system (patient) and the location of the potentially used health centers are crucial. In this context the topography of the area, the road infrastructure and the main means of transport are of interest to reflect the best the spatial access. Financial access is influenced by the costs for health care services at health centers that have to be seen in close connection to the health insurance status of the patient and – especially if the person is not insured – the availability of financial means. Also the costs for public transport if available play a role. Beyond the spatial and the financial access other factors are important for the utilization of health care on the one hand and the visit of a certain health center on the other hand. The patient first of all has to perceive the need of health care. The health center can influence the utilization by the organization in terms of opening hours and waiting time. Also the circulation of information from health centers within the population plays a role: Do people know about health care policies? Do they know about certain activities at the health center? Last but not least the perception of the health center's performance can influence the choice of the health facility: How is the perceived quality of health care and the attitude of the staff towards the patient?

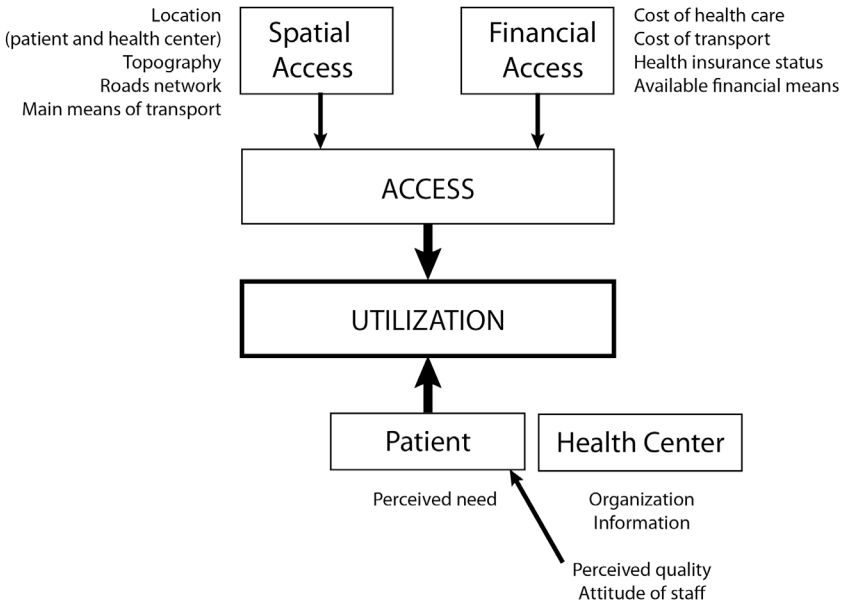

Figure 2.3: Own approach for analyzing the access and utilization of health care

2.3 GIS used for analyzing access and utilization

Spatial access can be interpreted as the regional availability of services and is commonly expressed by a physician/population ratio per an administrational unit like census blocks or districts or comparable indicators (JOSEPH & PHILLIPS, 1984; KHAN, 1992; see e.g. WHO, 2006). These "raw" ratios have been improved by considering for example Full Time Equivalent physicians or the population at risk instead of the whole population (KHAN, 1992). The remaining problem is that the measure is based on areal unit aggregates, without respect of spatial variations within the area. Furthermore, it does not consider the border crossing of potential patients (KHAN, 1992; JOSEPH & PHILLIPS, 1984). Luckily the technological development during the last 30 years gives health geographers new tools like geographical information systems (GIS) at hand (BLACK et al., 2004; KISTEMANN & SCHWEIKART, 2010:6; SCHWEIKART, 2007).

Beyond the above mentioned applications of GIS and remote sensing to disease related studies, where GIS was proofed to be an ideal tool "for a wide variety of surveillance, monitoring, and emergency response activities" (ALBERT et al., 2000:57), GIS has also become a useful tool in health care services research and planning (EARICKSON, 2009:18; KISTEMANN & SCHWEIKART, 2010:5). Though mainly in regards of physical accessibility also applications for "retail site analysis, transport, emergency service and health care planning" can be found (BLACK et al., 2004:2). In addressing the need for further research on the access to health

care the WHO for example has been developing methods and models for measuring geographic accessibility with help of GIS (BLACK et al., 2004; EBENER et al., 2005; RAY & EBENER, 2008). Health care systems all over the world experience disparities in the access to health care. GIS methods help to explore and to explain those disparities in order to counter them (KISTEMANN & SCHWEIKART, 2010:6; SCHWEIKART, 2007).

"GIS are well suited to measuring spatial accessibility to health care as they contain the core components needed for such analysis namely:

- Data capture storage, management and manipulation tools for both spatial and attribute (textual) data
- Core analysis algorithms such as buffering, overlay, proximity analysis, shortest path and raster cost-distance analysis
- Programming environments to customize and extend existing algorithms and create new analysis tools
- Mapping and visualization tools to communicate the results of analysis" (BLACK et al., 2004:2).

Also for developing countries the use of GIS technology has been proofed to be a powerful tool for analyzing and improving the physical accessibility and the utilization of health care (ALBERT et al., 2000; EBENER et al., 2005; NYKIFORUK & FLAMAN, 2011:69; PERRY & GESLER, 2000:1177). Some examples for the application of GIS methods to the problem of access and utilization of health care in sub-Saharan Africa will be given in the following.

2.3.1 Euclidean distances

Building a buffer or calculating Thiessen polygons for symbolizing the catchment area for a health facility are very simple methods in the context of analyzing the spatial accessibility of health facilities. They are based on Euclidean distances. Buffers draw circles or polygons in a defined distance (e.g. 5 km) around given locations (e.g. health facilities) or other input features like roads or areas (ESRI, 2012a). Those – in our case – circles can then be used to calculate for example the population in a certain distance around the health facility (ATTING & EGWU, 1991:212; MARTIN et al., 2002; TWIGG, 1990). ATTING & EGWU's (1991) accessibility study for example used 5 km buffers to create catchment areas for the health facilities in their study area in Nigeria (ATTING & EGWU, 1991:212). Thiessen polygons divide the area covered by a number of locations (health facilities) into zones "where any location within this zone is closer to its associated input point than to any other input point" (ESRI, 2012b). The construction of Thiessen polygons for representing catchment areas of health

facilities is an alternative to the more usual method of aggregating administrative boundaries (ALBERT et al., 2000). Compared to buffers they have the advantage to cover the whole study area and do not overlap.

ZWARENSTEIN (1991) for example used Thiessen polygons to visualize population to bed ratios in South Africa indicating the shortage of hospital beds in rural areas. NOOR et al. (2003) assessed the suitability and accuracy of Thiessen polygons in context of the utilization of health facilities in Kenya. These and other studies show that Thiessen polygons give a simple and intuitive possibility to divide an area into zones that can be assigned each to one health facility and to use these areas for further analysis (BLANFORD et al., 2012; NOOR et al., 2003; TANSER et al., 2001; ZWARENSTEIN et al., 1991). For analyzing the utilization of health facilities, Thiessen polygons imply the assumption that (1) all patients use the closest health facility (without taking into account the topography of the area), (2) all patients are travelling "along a straight line path" (NOOR et al., 2003:925) and (3) the utilization per capita is for the whole area the same independent of the distance to the health facility (GETHING et al., 2004:228; NOOR et al., 2003:925).

NOOR et al. (2003) use as a first step Thiessen polygons to calculate the theoretical target population of health facilities. In a second step they calculate the Euclidean distances between the enumeration areas (the smallest census unit in Kenya) and the next health facility to interpolate these distances into access surface maps for the study area (see also NOOR et al., 2004).

In order to improve the spatial accessibility of health facilities in Ghana OPPONG & HODGSON (1994) used Euclidean distances for calculating catchment areas for the existing health facilities. The authors found Euclidean distances to be a good measure because the patients are mainly travelling by foot. HEARD et al. (2004:170) used Euclidean distances as a proxy variable for the access to reproductive health care services in Malawi, while TANSER and colleagues used the average Euclidean distance as attraction factor for each clinic (TANSER et al., 2001:829). Euclidean distance has been used to establish a Distance Utilization Index (DUI) specifying the ratio of potential users with their distance to a specific health facility and the distances of all actual users. Thus a DUI bigger than 100 % shows that a big number from outside and from inside the assumed catchment area (Thiessen polygon) is attending the clinic, while a DUI below 100 % indicates a general poor attendance with people mainly coming from short distances within the catchment of the concerned clinic.

The optimum for an equal utilization would be to have DUIs of 100 % for all clinics (TANSER et al., 2001). A similar approach was used by TSOKA & LE SUEUR (2004) who also used Thiessen polygons for estimating catchment areas and calculated then the ratio of the population using the nearest health facility as well as the proportion of those living within a 5 km range of the health facility (TSOKA & LE SUEUR, 2004).

The appropriateness of Euclidean distances as a measure of accessibility is still discussed. Some authors argue that it is suboptimal because it does not consider physical barriers like hills and rivers, neither the transport system nor social factors (TANSER et al., 2001; citing SHANNON et al., 1973, and DEICHMANN, 1997). Still, TANSER and his colleagues found the method adequate for their rural setting with a high congruence of nearest and used clinic and the majority of the patients using walking as the primary means of transport (TANSER et al., 2001). Nevertheless, using Euclidean distances NOOR et al. (2006:192f.) found the population living within an one-hour distance from a health facility overestimated by almost 20 % and thus was including the transport network, elevation and other spatial barriers in an optimized model (NOOR et al., 2006:192f.; see also BLANFORD et al., 2012). Euclidean distances are considered to be often unrealistic, while "underestimating the effects of physical barriers such as major rivers or hills" (MARTIN et al., 1998:230; see also HAYNES, 2003).

2.3.2 Gravity models

A number of studies are dealing with the gravity model or further developed applications of it (FOTHERINGHAM, 1981; KNOX, 1978; LUO & QI, 2009; LUO & WANG, 2003; SCHUURMAN et al., 2010; WAN et al., 2012; YANG et al., 2006; see also JOSEPH & PHILLIPS, 1984; KHAN, 1992). Although gravity models have not been applied yet to the sub-Sahara African setting the method is worth noticing.

The two-step floating catchment area (2SFCA) method is based on the gravity model. Although its name suggests to be helpful in defining catchment areas, instead it is used for calculating access ratios (based on population-provider-ratios) that are not restricted to administrative boundaries. Instead a catchment area size is specified (e.g. in travel time via a road network or in straight-line distances). SCHUURMAN et al. (2010) for example estimated access scores for general practitioners per 10,000 people in an access area of two hours travel time by car. The enhanced 2SFCA method (E2SFCA)(LUO & QI, 2009; MCGRAIL, 2012)

overcomes the problem that the accessibility in the whole catchment pretends to be equally distributed (McGrail, 2012; see also Gething et al., 2004:228; Noor et al., 2003:925). Further improvements are applying different catchment area sizes which is helpful when the study area contains urban and rural areas (Luo & Whippo, 2012; McGrail, 2012). Wan et al. (2012) even introduced a three-step floating catchment area (3SFCA) method minimizing the problem of overestimating healthcare-demand. The 2SFCA method and its improvements (Luo & Qi, 2009; Luo & Wang, 2003; Wan et al., 2012) have been used in context to access to health care for example for study areas in rural Canada (Schuurman et al., 2010) or rural Australia (McGrail & Humphreys, 2009; McGrail, 2012), Ohio (Khan, 1992), Illinois (Luo & Qi, 2009; Luo & Whippo, 2012), Chicago (Luo & Wang, 2003; Wang & Luo, 2005; Yang et al., 2006), and central Texas (Wan et al., 2012) but not yet for areas in sub-Saharan Africa.

In context with consumer behavior and market share analysis the Huff model has been used for more than 40 years. Huff (1963) defined a version of the gravity model that is mainly based on a distance decay parameter (Huff, 1963; referenced in Huff, 1964; Huff & McCallum, 2008). Including an attractiveness factor for each facility, it gives the probability of a person in location *i* traveling to a supplier in location *j* (Griffith, 1982; Huff, 1964). The model received even more attention with its integration in GIS (Huff & McCallum, 2008). A full application is for example available with the Business Analyst extension in ArcGIS (Huff & McCallum, 2008). A reduced and free tool has been developed for ArcGIS by Flater (2010). Being conceptually advanced the model is criticized being not very intuitive or transparent (Luo & Wang, 2003) although its inventor describes it as easy applicable as well as its outcomes easily understandable and communicable. Nevertheless, the distance decay parameter has to be estimated empirically which requires additional data and might be depending on the region (Huff, 2000; cited by Luo & Wang, 2003; see also Huff, 1964, 2003). In his study Luo (2014) combines the Huff Model with the FCA method to adjust the population demand on health care services.

2.3.3 Network analysis

In the present context, network analysis is understood as a vector based approach on basis of a given road network. Within ArcGIS for example the road network is stored in a so called Network Dataset that includes the roads as lines but also how they are connected to each other.

Network analysis modules in a GIS offer for example Service-Area-Analysis or Closest-Facility-Analysis. Service-Area-Analysis calculates the area that can be reached in a certain (travel) distance or – if this information is available for the road network – in a certain travel time. Those areas can then be used for example to calculate the population served in the given distance of health centers or to calculate the area that is not covered. The Closest-Facility-Analysis assigns the nearest health facility to given points (for example households or villages) and gives information about travel distance, travel costs or travel time (depending on the available data; ESRI, 2012d; NYKIFORUK & FLAMAN, 2011:68). Although NYKIFORUK & FLAMAN (2011) see a close connection between GIS analysis of health access and analyzing market segmentation and network analysis, "extensively used in [...] developing countries" (SHAW, 2012:91) their applications remain limited.

Not for Africa but for rural Canada SCHUURMAN and her colleagues (2006) used a road network to define the catchment areas for hospitals based on travel-time. Doing so they were able to calculate the share of the population living within one hour travel-time of a hospital (SCHUURMAN et al., 2006).

Although a “number of studies have revealed differences in outcome between straight-line distance analysis and that based on actual transport network” (NOOR et al., 2003:925) road or transportation networks were used in Africa until now mainly as an input feature for the performance of raster based approaches like the cost distance analysis (NOOR et al., 2006; TANSER et al., 2006, see below).

The only exception found is the study of MURAWSKI & CHURCH (2009:102): They were looking at the accessibility of rural health services in Ghana, where it was hampered by the lack of all-weather roads. They showed “[...] that even a modest level of road improvement can lead to substantial increases in all-season access to health service” (MURAWSKI & CHURCH, 2009:102).

Not for assessing the access to health care but to evaluate the accessibility to secondary schools in Nigeria, OGUNYEMI and colleagues (2014) used network analysis

methods. They evaluated the nearest school for the students and calculated medium travel times for each secondary school in the area.

2.3.4 Cost distance algorithms

Cost distance algorithms are using a so called cost layer, measuring the "effort" for example in terms of travel time that is needed to reach given destinations, like health centers in this case, from any point in the study area (for technical details please refer to section 4.2.3.3). The accuracy of the results is dependent on the defined "cost" and the available details of the landscape (GETHING et al., 2012).

TANSER et al. (2006) include in their cost layer the road network with its position and its quality, natural barriers as well as the share of the population that is using public transport to reach a health facility in their study area in South Africa. In their raster grid of 30 x 30 m resolution all barriers to movement were assigned the value -1 indicating an absolute barrier. The walking speed on roads was defined as 4 km/h, 3 km/h on tracks, and off-road 2 km/h. They developed models for the population using mainly public transport and another model acknowledging the share of the population that is travelling only by foot (TANSER et al., 2006).

A similar approach was used by NOOR and colleagues (NOOR et al., 2006) in Kenya. For each grid pixel (100 x 100 m) the speed depending on the surface was specified representing the time in minutes that would take it to cross the pixel. Barriers like rivers, forests and parks were again defined as impassable except of where roads were intersecting. They based their travel time estimates for travelling by foot on roads (5 km/h) and off-road (2.5 km/h) on the Naismith-Langmuir rule that also considers the slope at each pixel (LANGMUIR, 1984; NAISMITH, 1892; cited by NOOR et al., 2006:190). GETHING et al. (2012) used the same travel time estimates for their study about spatial access to care in Ghana, focusing on the situation of giving birth. Additionally they developed an optimized and calibrated model for travelling by other means of transport. Barriers like rivers and lakes are included in the model with higher impedance resulting in an "appropriate time delay" (GETHING et al., 2012) – unfortunately the authors do not specify what "appropriate" exactly means in these circumstances. It is also not clear if they considered the elevation.

For their study about the utilization of health facilities in the West Province of Rwanda, HUERTA MUNOZ & KÄLLESTÅL (2012) assigned travel speeds of between 1 and 5 km/h for the

walking model to different types of landuse. The same landuse data is used to specify four different levels of population density to develop a dasymetric population density map (see SLEETER & GOULD, 2007). They used the data for executing the moduls of the extension AccessMod for ArcGIS, developed by the WHO. It uses the defined travel speeds for the land use, combines it with the road network travel speeds and the population layer and calculates the share of the population that can access the next health facility in an hour's time (or another defined time). Also the digital elevation model is considered in this analysis with a resolution of 90 x 90 m. The extension allows the definition of different travel scenarios.

2.3.5 Estimations of travel times

In the majority of studies either distance or walking travel time has been used for evaluating the accessibility of health care in sub-Saharan Africa. In the aim of estimating the population that is living within a travel time of one hour from the next health facility the travel speed plays an important role. The choice of a travel speed or a cost algorithm remains difficult in the Rwandan landscape: lack of public transport makes travelling by foot the mainly used mean of transport while the illness of patients seeking for health care might make travelling by foot even more difficult (LEWANDO HUNDT et al., 2012).

The AccessMod extension applies for example TOBLER's formula (TOBLER, 1993) that he established for more realistic time- or cost-distances on variable terrains based on empirical data given by IMHOF (1950):

$$W = 6^{\{-3.5 \times |S + 0.05|\}} \quad (1)$$

where W is the walking speed and S the slope (TOBLER, 1993). This results in a maximum walking speed of 6 km/h on a slight descent while assuming a decrease of speed with an increase of slope. Descending is characterized by a slightly higher speed than ascending at the same slope. The travel speed on flat ground is with this formula estimated with about 5 km/h which can already be quite challenging for a sick person.

NOOR and colleagues (2006) are basing their travel time calculations on a rule by LANGMUIR (LANGMUIR, 1984) who improved an old but simple formula of NAISMITH (1892)"[...] that may be found useful in estimating what time men in fair condition should allow for easy expeditions, namely, an hour for every three miles on the map, with an additional hour for every 2,000 feet of ascent" (NAISMITH, 1892:136). LANGMUIR added a decrease of travel time

of 0.03 minutes per 1 m moderate descent (-5° – -12°) and an increased travel time of 0.03 minutes per 1 m descent of more than -12° (LANGMUIR, 1984; cited in NOOR et al., 2006). NOOR and colleagues (2006) applied an average travel speed of 5 km/h on roads and 2.5 km/h off-road. With the LANGMUIR rule the maximum travel speed is 7 km/h at a slope of -12°. Beyond the fact that the break values of -5° and -12° give very drastic cuts in the in- and decrease of travel speeds (see Figure 2.4) it also seems hardly imaginable to see a sick person walking at that speed.

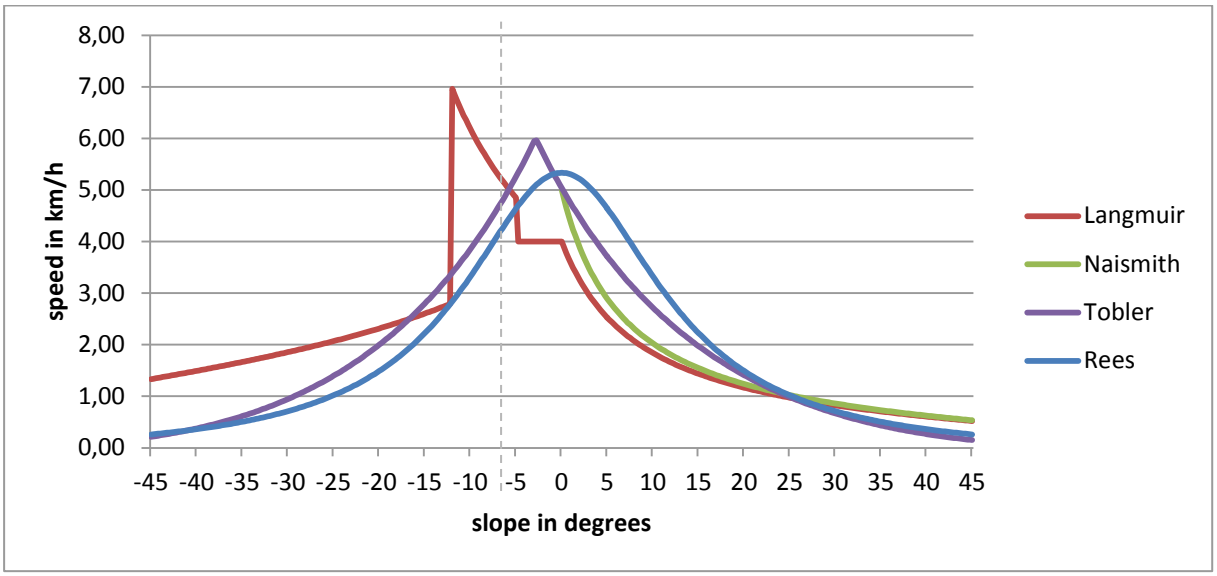

Figure 2.4: Comparison of travel speed formulas

A more advanced approach was done by REES (2004) in an attempt to calculate least-cost paths in mountainous terrains. He suggests to calculate the effort with the quadratic function

$$\frac{1}{v} = a + bm + cm^2 \qquad (2)$$

with the speed v and the slope m, defined by dh/dx where dh is the gained height and dx the travelled horizontal distance. In previous research (REES, 2003; cited in REES, 2004) he found the coefficients $a = 0.75\ s/m$, $b = 0.09\ s/m$ and $c = 14.6\ s/m$ to be suitable values, though the value b can be set to zero "without significant loss of accuracy" (REES, 2004:204). The coefficient a gives the travel speed of 4.8 km/h on plain ground while the parameter c specifies how fast speed is decreasing with the increase of slope. Simplified he calculates the costs of travelling from one point to another with

$$k = ad + c\frac{h^2}{d} \qquad (3)$$

while d is the horizontal distance between the two points and h the vertical distance. The formula has the limitation but also the advantage that the costs are independent of if the given path is ascending or descending. Additionally it favors the indirect path, walking zig-zag, instead of walking straight, from a critical value for the slope. Considering that in the cost distance model only straight (0°) or diagonal (45°) movements between grid cells are possible, this critical value is reached at a slope of about 15 degrees (27 m height on 100 m horizontal distance).

3 The regional context: Rwanda

This thesis is focusing on the utilization of health centers in Huye District in the south of Rwanda. To get an impression of the setting, Rwanda as well as its health care system will be introduced in this section.

Rwanda, unfortunately often memorized as the country of a million victims of civil war and genocide, is a rapidly developing country in the center of Africa, belonging to the East African Community (MINECOFIN, 2012; NISR et al., 2012:2; UNDP, 2012a). Coming here for the first time, tourists are often astonished by the tidiness of the capital city of Kigali and its skyscrapers in the city center. Nevertheless, Rwanda is still a poor country with a high share of rural areas and a population that makes its living mainly from subsistence farming. In the country side roads are in poor conditions – one reason for a lack of public transport in these areas. People travel mainly by foot which is hampered by the hilly terrain as well as the rainy seasons that worsen the road conditions and transform small streams into impassable rivers.

3.1 Geographic and climatic conditions

The Republic of Rwanda is located in the heart of Africa, slightly south of the equator between 1°4’ and 2°51’ south latitude and between 28°63' and 30°54' east longitude, measuring about 250 km from northeast to southwest and 170 km from northwest to southeast. Rwanda is a land-locked country, neighbored by Uganda, Tanzania, Burundi and the Democratic Republic of the Congo with no navigable water route connections to the oceans. With only 26,338 square kilometers Rwanda is the second-smallest country south of Sahara which is comparable in size to Haiti or Macedonia (MOH et al., 2009:1; OPPONG, 2008; see Figure 3.1).

Rwanda predominantly consists of rolling hills, leading to its soubriquet “Land of a Thousand Hills”, with elevations between 1,500 and 2,000 meters. The Virunga volcano chain, part of the Albertine Rift, in the northwest includes also Rwanda’s highest point, the summit of Mount Karisimbi at 4,507 meters. In contrast, the eastern region levels gradually into flat low-lands, with savannah, plains, swamps, and lake-filled valleys with elevations in general below 1,500 meters (MOH et al., 2009:1; NISR et al., 2012:1). The valleys between the hills and mountains contain a dense network of rivers and streams (MOH et al., 2009:1).

Figure 3.1: Overview of Rwanda and its position in Africa

The high elevation is the reason for Rwanda's temperate, sub-equatorial climate with yearly average temperatures of about 18.5 °C. Rwanda is influenced by two rainy seasons per year, one from mid of February to end of April and one between mid of September and December with an average annual rainfall of 1,250 mm. Despite the mainly constant temperatures, Rwanda experiences a varying climate from year to year resulting in drought or, less often, flooding, which both severely affect the agricultural production (NISR & MINICOFIN, 2006:5).

3.2 The Genocide and its consequences

The population of Rwanda belongs to the ethnic and linguistic group of the Banyarwanda, and Rwanda as a country has its roots probably 1000 years ago (KUMAR & MILLWOOD, 1996:2). Rwandans always shared one language, one culture, and the same moral values. Within the Rwandan people three groups can be distinguished which do not correspond with any races, tribes or ethnicity. The original distinction of Hutu, Tutsi, and the Twa was more or less a sociological classification: Someone with more than ten cows was called Tutsi; someone who made his living from agriculture was said to be Hutu; someone

living from hunting and collecting fruits was Twa. The separation of the Rwandan people into so-called 'races', the Hutu (Hutu-Bantu), the Tutsi (Tutsi-Hamites), and the Twa (Twa-Pygmoids), and favoring first the Tutsi and later the Hutu during Belgian colonialism is seen as one of the many root-causes that led Rwanda into civil war and culminated into the genocide of 1994 (BATWARE, 2012:2; BBC NEWS, 2011; MUSAFIRI, 2012; SHYAKA MUGABE & TUYISABE, 2007:22; SOCIALIST WORKER, 2004; see also HINTJENS, 1999 and BRAECKMAN, 1994). Before the genocide the census of 1991 reported a share of 90 % Hutu, 8 % Tutsi and less than 1 % Twa (KUMAR & MILLWOOD, 1996:2).

Since its independence in 1962 Rwanda experienced a lot of violence against the Tutsi and moderate Hutu, culminating in numerous deaths and refugees looking for shelter in neighboring countries (SHYAKA MUGABE & TUYISABE, 2007:23). Violence reached its peak during four years of civil war and ultimately with the genocide from April to July 1994 when about one million people were killed (CANTWELL, 1997; KINZER, 2008:192; MELVERN, 2000; REYNTJENS, 1997).

After the genocide the country was left devastated: The whole land had been plundered; most of the schools, hospitals and health centers, like all public buildings, have been damaged and looted; stocks of drugs and health supplies have been pillaged, equipment left unusable. No office was left intact, there were no chairs, no desks, even doors and windows were missing. The country's infrastructure was destroyed: telephone, radio communication, electricity, water supply lines were non-operational. Ten years later, the output of electricity, water and gas was still 30 % under the level of 1990 (UN, 2006:6f.). Private homes have been ransacked and demolished, cattle killed, fields ravaged. 80 % of health professionals and more than half of the teachers were killed or had left the country. There was no judicial system to enforce the law or to protect the population (BASINGA et al., 2008; BOUCHET-SAULNIER, 1994; CANTWELL, 1997:28f; GIEP/OAU, 2000:190; KUMAR & MILLWOOD, 1996:20; MEESSEN et al., 2006:1305; MELVERN, 2000:222; SELLSTRÖM et al., 1996). Lack of human and financial resources made it difficult for the newly established government to rebuild the country and to give justice to the people that were "physically, emotionally, psychologically and spiritually" decimated by the genocide (President Paul Kagame in the Preface to CLARK & KAUFMAN, 2009:xxi; SELLSTRÖM et al., 1996:57f.).

Twenty years after the genocide Rwanda has remarkably developed, yet not fully recovered from genocide and its ideology (KINZER, 2008:325f.). The current government defeats the distinction between Hutu, Tutsi and Twa.

3.3 Current administrative structure of Rwanda and its population

In 2006, Rwanda was administratively reorganized. Its former twelve provinces were restructured into five (City of Kigali, North, South, East, and West), mainly following the geography of the country (MOH et al., 2009:2). The provinces (*Intara*) consist of 30 districts (*Akarere*), which are divided in 416 sectors (*Umurenge*), 2,185 cells (*Akagari*), and 14,837 villages (*Umudugudu*)(NISR et al., 2012:2; NLC, 2010; see Figure 3.2). The district is the basic political-administrative unit of the country[1]. With the preparation of the census in 2012 the boundaries of all villages have been captured and classified as rural, peri-urban or urban areas.

In this context, the term village shouldn't be associated with a dense group of houses in a rural area. It can rather be described as an aggregation of scattered settlements (ISAKSSON, 2013:395; TAKEUCHI, & MARARA, 2000:5). TAKEUCHI & MARARA (2000) are giving a very pictorial description: "Typical scenery in this country is that of hills cultivated up to their tops and

Figure 3.2: Administrative structure of Rwanda

[1] In the last years new names for the districts and its capital cities were introduced but are not widely used in the population. Those new names are stated in brackets in the following.

dotted with a few small houses" (TAKEUCHI, & MARARA, 2000:5, see Figure 3.3). After the civil war and genocide in 1994 when a lot of houses were destroyed or taken by other families, international organizations and NGOs launched programs to give shelter to the homeless or the returning refugees. Because those shelters were built in groups they were called "*umudugudu*" in the local language Kinyarwanda, meaning "village" or "agglomeration of houses" (TAKEUCHI, & MARARA, 2000:29). In this context Rwanda introduced its villagization or *Imidugudu* program that started "as an emergency housing project […]" which soon "was redefined as an ambitious development program establishing that *all* households living in scattered rural homesteads […] should be regrouped into organised government/donor constructed village settlements" (ISAKSSON, 2011:1; see also HILHORST & LEEUWEN, 2000:264). In addition to addressing the problem of settlements and land use, the main intention of the program was the hope that it would promote markets to develop more easily and to stimulate income-generating activities that are not based on agriculture (HILHORST & LEEUWEN, 2000:267; ISAKSSON, 2013:395). By 2011 almost 68 % of households were clustered in *Imidugudu* (MINALOC, 2014:1), consisting of between 100 and 200 houses (MINECOFIN, 2012:31). For the National Census 2012 the National Institute of Statistics mapped all villages with their boundaries.Despite the progress in villagization, in rural areas houses are still often scattered over the area within the defined villages which makes it difficult to give them a central geographical position.

With a population of 10.5 million inhabitants Rwanda has the highest population density in the East African Region: 415 inhabitants per square kilometer in 2012 (NISR & MINECOFIN, 2012b). The national sex ratio is 93 males to 100 females (NISR, 2012a:4). The population is rather young with about 50 % of all Rwandans under the age of 20 years (NISR, 2012a). The population is predominantly rural, with a few larger towns like the capital Kigali,

Figure 3.3:
Village in the country side (South Province)
© Nicole Ueberschär

with an estimated population of around one million, followed by Butare (Huye), Gitarama (Muhanga), Ruhengeri (Musanze) and Gisenyi (Rubavu). The census data of 2012 numbers the share of the population living in rural areas as 83 % (NISR & MINECOFIN, 2012b).

Numerous religions can be found in Rwanda. Nevertheless 93 % of the population allegedly practice some form of Christianity, the majority are Catholic. This is also represented by those health centers that are not public: so called agreed facilities are often run by Christian communities (see 3.7). The number of Moslems is increasing and was numbered with about 2 % in 2002 (NISR et al., 2012:3).

Kinyarwanda is Rwanda's official first language; it is spoken by nearly all Rwandans. While a long time French was the second official language in the country, it was complemented by English in 2010. Kiswahili is the third most common foreign language which is mainly spoken in urban areas and in those regions bordering Kiswahili-speaking countries, like Tanzania and the Republic of the Congo (NISR et al., 2012:3).

3.4 Economy and education

In recent years the service sector's contribution to the economy has been higher than the agricultural sector's. Still, the main share of the population is working in agriculture (86 % of women, 62 % of men), most of them living on subsistence farming (MOH et al., 2009:2; NISR et al., 2012:2).

Although the visit of a primary school for six years and three years of lower secondary schooling is mandatory in Rwanda (MINEDUC, 2013:1) and although the children don't have to pay school fees up to this level at public schools, the mean number of years a Rwandan spends on education is only 3.3 years (UNDP, 2010:145). The country's literacy rate, defined as those aged 15 or over who can read and write, was 71 % in 2010, which is better than the average of the developing countries in Sub-Saharan Africa with 60 % (THE WORLD BANK, 2013a).

While poverty has declined since 1994, still almost 57 % of the population is poor, with 90 % of the poor living in rural areas (NISR, 2006:viii). Also female headed households are more strongly affected by poverty: 60 % of households that are led by a woman live in poverty (NISR, 2006:11). In this respect it is worth noticing that in one third of households in Rwanda women are the heads of the families (NISR et al., 2012:13).

3.5 Communication and technology

The Rwandan Government with implementing its "Vision 2020" recognized by end of the last century the necessity of an improved internet access and telecommunication for a prosperous development of the country (MINECOFIN, 2000). In the meantime, Rwanda is ranking among the countries with the fastest internet connectivity speed in Africa[2] as a result of an increasing bandwidth and the National Fiber Optic Backbone. Still, rural areas until now do not profit sufficiently from this development. Ownership of personal computers, smartphones or TV is very limited in these areas (MYICT, 2012). By 2009 in the whole country 59 % of households were possessing a radio, only 4.3 % a TV (NISR, 2013:84).

Nevertheless, by 2012 the four telecom operators had registered almost 5.7 million cell phone users; 54 % of households are possessing at least one cell phone (MYICT, 2012; NISR, 2014). Calling rates have been decreasing over the last years, partly due to the competition between the three private providers: As of September 2012, calling rates were ranging from 20 to 90 RWF (about 0.04 to 0.14 USD)(THE WORLD BANK, 2013b:5). 97 % of the population are covered by mobile cellular networks while less than 50,000 users are connected via a fixed telephone line (NISR, 2013).

For the health sector this development has been favorable: by 2011 all district hospitals and 97 % of the health centers were equipped with cell phones, internet access was provided at 83 % percent of the health centers and for all district hospitals, and at almost all of these health facilities computers have been available (NISR, 2013:50). Furthermore, several information and communication technology initiatives have been implemented over the last years in the health sector, that facilitate the nationwide tracking of patient data as well as the central collection of clinical information, and which allow community health workers to collect data for those systems using their cell phones (THE WORLD BANK, 2013b:6).

3.6 Road network and public transport

Rwanda provides a dense network of roads connecting all bigger cities of the country with Kigali. The big "backbones" of the road network are the national roads with a total of 2,881 km which take the biggest share of paved roads (almost 1,200 km of about 1,400 km), increasingly equipped with street lights. They are reported in 2011 to be at 98 % in good

[2] http://www.netindex.com/download/allcountries/

condition (MININFRA, 2012:iii). These roads are intensively being used for international transport of goods and travelers. The district roads are in general unpaved roads, but they are better maintained than other roads. All those other roads are building a network of more than 32,000 km connecting the villages to the bigger cities. Except of minor portions within urban areas the roads are not paved and in generally very bad condition. During the rainy season they might even be impassable or only accessible with a four wheel drive (MININFRA, 2012:iv; NISR, 2012c).

Since there is no railway network in Rwanda, the land public transport is solely provided on roads. The main public transport vehicles are small mini busses called taxi, operating on national and district roads. Bigger busses are available as well but on higher travel costs. They offer space for 25 to 33 passengers. At present 41 companies and cooperatives are registered to provide public transport with different types of vehicles, with the major market share coming from individual operators (MININFRA, 2012:ii). For shorter distances motorcycles and even bicycles are used for public transport, the latter especially in rural areas. Taxi cabs provide only 3 % of the passenger capacity and are only available in urban areas (MININFRA, 2012:iii). While the current public transport services in general are said to be inefficient and costly (MININFRA, 2012:iii), in the rural areas it is even worse which fosters one of the main barriers to accessing health care (see Table 2.1). Since the initial and operating costs for providers are higher for services on bad roads, those are mainly covered by ONATRACOM, the sole bus service provider under public management (MININFRA, 2012:v).

Taking into account that only about 50,000 cars including Jeeps and Pickups and about 60,000 motorcycles are registered in Rwanda, as well as the low percentage (13 %) of households owning a bicycle (MININFRA, 2012:17; NISR, 2006:10), it is obvious that in rural areas where public transport is poor the main mean of transport is to go by foot. This increases travel time to health centers significantly and makes travelling for seeking health care time-expensive and exhausting.

3.7 The Rwandan Health Care System

3.7.1 Historical development of the health care system in Rwanda

Health care in Rwanda experienced substantial changes over the last two centuries. Before colonization, traditional medicine using plants, powders, and herbs to treat diseases constituted the basis of health care provision. With the arrival of the Germans end of the

19th century, the transition to modern medicine started, and also religious institutions "played an important role in this process" (NISR et al., 2008:11). Until the war and the genocide in 1994, a strong centralized system was characterizing Rwandan health care. Theoretically, health services were free to all Rwandans. Religious institutions were still widely engaged in the system (NISR et al., 2008:11).

After the 35th session of the African Regional Committee of the World Health Organization in Lusaka in 1985, Rwanda started a decentralization process towards transferring the managerial responsibilities to the district level (NISR et al., 2008:12). The international conference on primary health care that took place in Alma Ata in 1978 appealed for implementing worldwide health care, especially in developing countries (BASINGA et al., 2008:93; HALL & TAYLOR, 2003; HUERTA MUNOZ & KÄLLESTÅL, 2012; RIFKIN & WALT, 1986; WHO, 1978). In consideration of the Alma Ata Declaration, Rwanda introduced a primary health care policy committed on "developing a basic health system that offers primary health care responding to the needs of the population" (NISR et al., 2008:12).

After the war and the genocide in 1994, also the health system of Rwanda was mainly destroyed. The loss of human capacity for health care was high (BASINGA et al., 2008). Soon Rwanda started to rebuild human resources for health and to reform its primary health care system. In 1996 the Rwandan Government of National Unity adopted the health sector reform initiative launched by the Ministry of Health already in February 1995. Its objective was to ensure the delivery of quality health services in the whole country aiming to enhance the well-being of the population. These services aimed to be approved by and available for the majority of the population. From the beginning of the new century, a continuous development can be observed (NISR et al., 2008:11f.).

With the aim to guarantee "access to health and wellbeing to the entire population, and in addition, increasing production and reducing poverty" (MOH et al., 2009:4) the government of Rwanda adopted the health sector's policy as well as the 2005–2009 Strategic Plan of the Ministry of Health in 2005. Special emphasis is also laid on reproductive health issues including facilitating safer pregnancies, "children's health, family planning, sexually transmitted infections (STIs), HIV/AIDS, teenage reproductive health, prevention and response to sexual violence, and social changes aimed at increasing women's decisionmaking power" (NISR & MINICOFIN, 2006:4). Additionally the Ministry of Health is encouraging "highly qualified medical personnel to serve in rural areas" (NISR & MINICOFIN, 2006:4).

3.7.2 Current Situation

The health system in Rwanda is a decentralized, multi-tiered system. It consists of a central level, based in the capital, as well as a peripheral level that consists of 30 administrative districts (NISR et al., 2008:13f.). Four types of hierarchically dependent health facilities can be found, with associated packages of health services (see Figure 3.4 and Table 3.1; MOH, 2010a, 2013).

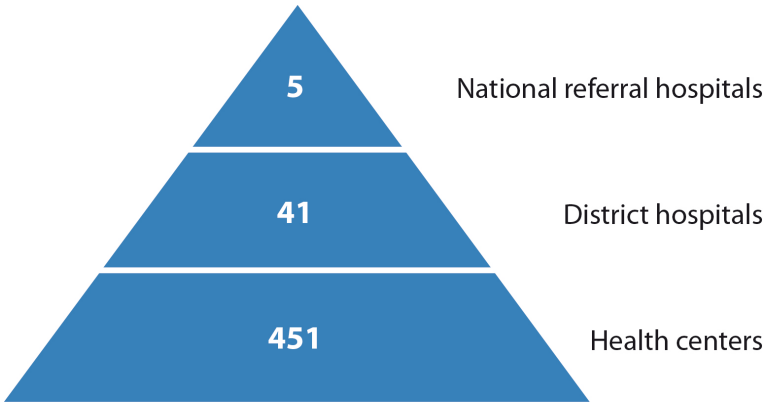

Figure 3.4: The pyramidal structure of Rwanda's health care system (BASINGA et al., 2008:94), counts by 2012 (MOH, 2012:12)

Table 3.1: Packages offered by health facility

Type of health care facility	Package of offered health care services
National Referral Hospitals (5)	Inpatient/outpatient services , surgery, laboratory, gynecology, obstetrics; radiology
District hospitals (41)	Inpatient/outpatient services, surgery, laboratory, gynecology, obstetrics, radiology
Health centers (451)	Prevention activities, primary health care, inpatient, referral, maternity
Health posts (125)	Outreach activities (immunization, family planning, growth monitoring, antenatal care)

Source: MOH, 2010a:227; counts by 2012 (MOH, 2012:12).

The pyramidal structure of Rwanda's health care system is based on the health centers. In contrast to health posts that are also able to provide primary health care services, health centers offer also prevention activities as well as inpatient and maternal services. Nevertheless, health posts offer a reduced package but cover those areas that are far away from a health center and are mainly responsible for outreach activities. If necessary, health centers can refer patients to the district hospital where doctors are available who can provide specialized treatment and surgeries. They build the medium level of the health care

pyramid. In severe circumstances a patient can then be transferred to one of the national referral hospitals, the top level of the pyramid: the University Teaching Hospital in Kigali (CHUK), the Kanombe Military Hospital in Kigali, the King Faisal Hospital in Kigali, the University Teaching Hospital in Butare (CHUB), and Ndera, the referral hospital for neuropsychiatric disorders (BASINGA et al., 2008:94; MOH, 2012:12). Patients are also accepted without being referred from a lower facility but in this case in general their treatment is not covered by Mutuelle de Santé (see section 3.7.4).

In the average a health center serves a population of about 20,000, but of course these numbers vary widely between rural and urban areas. The number of health centers indicates that every sector has at least one health center. But considering that one nurse (including nurses at hospitals) has to serve more than 1,200 patients, the supply of primary health care can be seen as not sufficient (NISR, 2013:48). The general shortage of human resources in the health sector is even more serious in rural areas (NISR et al., 2008:14).

The public sector is assisted by religious and private institutions. In contrast to the private facilities the religiously managed health centers are integrated into the public health system by agreements. They are offering mainly the same services as the public health centers. Private health facilities are mainly situated in urban areas: 70 % of them (in total 375) can be found in Kigali City or its surroundings (NISR et al., 2008:15).

For a better contribution of resources it is planned that all health centers shall be equipped with an online tool that will be used to assign villages to the catchment areas of health centers. Based on the detailed knowledge about where their patients come from, the staff at health centers will directly be able to optimize the catchment areas (Wilson, MSH, 2011). With the results of the utilization analysis presented in chapter 5, this study offers a computer-based method of determining the optimal assignment of a village to the best suitable health center.

3.7.3 The community level

In 2009 a program was introduced aiming to strengthen, extend and improve services for the promotion of health and the prevention of diseases (MOH, 2010a:43). In this context, the project Community-based Integrated Management of Childhood Illnesses (C-IMCI) at village level was implemented (MOH, 2010a:133). For each village, a group of five persons shall be selected: one couple of community health workers (CHWs), another couple of CHWs

for maternal and child health, and one person responsible for social affairs (UWIZEYE, Huye District, 2011). CHWs in charge of maternal and child health, formerly called traditional birth attendants, are trained to monitor critical events in the maternal status and for new born babies up to nine months. Their role has been revised to strengthen the sensitization and to improve the support for pregnant and post-natal women. With the aim to reduce the maternal and neonatal mortality they encourage pregnant women to deliver at a health center while refusing to assist with a home birth (MOH, 2010a:135). CHWs provide care for children aged less than five years. Depending of the severity of symptoms they refer the child to a health center or hospital, or they treat the children themselves, i.e. against fever, diarrhea, and symptoms of pneumonia. CHWs are also trained to provide a selected package of family planning services (MOH, 2010a:136). The role of community health workers is increasing as this policy gets more and more established in the districts. In 2010 there have been already 45,000 CHWs in the country. The Ministry of Health aims to reach a number of 60,000 CHWs (MOH, 2010a:139). It can be observed that CHWs are addressing far more children than the health centers. Meanwhile the effective treatment is almost equally balanced between health centers and CHWs (MOH, 2010a:133f.). At the time of this study, CHWs have not yet been implemented in the study area.

Rwanda's health care system can be described as mainly 'biomedically' oriented, including "diagnosis and curative treatment of the patient's illness or disorder" (EARICKSON, 2009:16). The focus of this study is on primary health care provision and utilization with primary health care in Rwanda being comparable to a level of care which, in 'Western' countries, is provided by community nurses and general practitioners (JOSEPH & PHILLIPS, 1984:1).

3.7.4 Health insurance schemes in Rwanda

Rwanda's health system is financially based on state funds as well as on contributions of individuals paying regular health insurance plus additional fees for health services (MOH, 2013:1). The government of Rwanda initiated three reforms in the field of health financing in order to increase the demand for and the supply of health services. One is patient-based, intending to reduce the financial barrier to health care utilization by means of health micro-insurance schemes ("Mutuelle des Santé"). The second reform targets the health facilities in order to improve service delivery by means of performance-based financing (PBF). The third

reform is a fiscal decentralization, giving the districts more financial power in the health sector (SEKABARAGA et al., 2011).

Already in the 1960s, the first community based insurance systems were introduced. After being re-established in 1996, the initiative of a community based insurance system did not develop well in the first years. But around the turn of the millennium the development increased rapidly. Some authors name RAMA (Rwandaise d'Assurance Maladie) to be the first introduced health insurance theme that was established for civil servants and the formal sector in 2000 (SEKABARAGA et al., 2011), other authors date the introduction of the communal insurance scheme Mutuelle de Santé already to 1999 (LOGIE et al., 2008:258). While health insurance coverage was negligible at this time, in 2005 already more than 40 % of the population were subscribed to a health insurance scheme (SEKABARAGA et al., 2011). The Mutuelle de Santé program is organized in a decentralized structure: main tasks are located at sector level while the district administration is only responsible for monitoring and evaluation. Although membership within the Mutuelle de Santé is voluntary, the affiliation to any health insurance is compulsory – at least theoretically but in 2010 not yet legally enforced (MOH, 2010a:34; SEKABARAGA et al., 2011). In 2011 the annual premiums were increased from 1000 RWF (1.5 USD) per person to 3000 RWF (about 4.4 USD) or more, depending on the economic status of the family. All family members have to be insured to avoid that only old people and children contribute to the payments. For families that are too poor to pay the health insurance fee, the costs are subsidized by donors. A committee elected by the inhabitants of the village decides who is considered too poor. Additionally, persons suffering from HIV/AIDS, and their families who are attending a PEPFAR program, do not have to pay. In 2004 10 % of the population was excused of paying their fees, estimates in 2005 were suggesting waiving the contributions for 15–30 % of the poorest population (LOGIE et al., 2008:259). In 2007 the fees for almost 200,000 orphans and HIV/AIDS patients were paid by the government (BASINGA et al., 2008).

The insurance covers health services at all public and non-profit health centers in Rwanda but not at private health centers. Still patients have to pay a fee of 200 RWF for consultations, and 10 % of the total costs as a service fee for each visit to a health center or hospital (LOGIE et al., 2008:259; MOH, 2013). By 2010, in 78 % of households at least one person was covered by health insurance, 98 % of them through Mutuelle de Santé (NISR et al., 2012:31), SEKABARAGA et al. (2011) report a coverage status of 91 % for 2008 including all health insurance schemes (SEKABARAGA et al., 2011). A slightly higher percentage of women

(71 %) than men (66 %) are insured, the same applies to older persons who are more likely to be insured (>70 % women/>67% men) than younger women and men (64 %/62 %)(NISR et al., 2012:31). For the year 2011/2012 about 91 % of the population was reported to be insured with the Mutuelle de Santé (MOH, 2012:78).

The principle of "patient roaming" implies that patients must register with the Mutuelle de Santé in the sector they live but can use the health services at any health center in the country (FISCHER, GTZ, 2010). Information from the Huye District reveals that patients can register at any sector but only one. Patients have to choose this health center for utilization of health care, otherwise they have to pay the amount as those who are not insured at all. Only in case of emergency or other serious issues, patients are allowed to use other health centers with the costs covered by Mutuelle de Santé (NTAKIRUTIMANA, Huye District, 2011).

Besides the Mutuelle de Santé Rwanda has a number of health insurance schemes which are used mainly by people working in a certain sector. One example is the former National University of Rwanda (NUR) which insures all employees in its own health insurance. Furthermore, the military has an own health insurance (MMI – Military Medical Insurance). At Sonarwa (Societé Nouvelle D'assurance du Rwanda) only certain employment groups can register, RAMA (La Rwandaise d'Assurance Maladie) is a para-governmental health insurance for governmental employees, and FARG (Fonds National pour l'assistance aux Rescapés du Génocide) is a special fund for the victims of the genocide of 1994. Statistically those insurances are mainly used by married women and men living in Kigali City or other urban areas, who have at least secondary education and belong to the wealthiest portion of the population (NISR et al., 2012:31). The high coverage of the population by health insurance schemes contributes to an improved financial accessibility and facilitates the utilization of health care (compare Table 2.1).

4 Methodology

This chapter provides an overview of the methods used in order to achieve the defined objectives. A mixed method approach is applied, using retrospective data, data from an own survey, spatial analysis and the input of experts to include their expertise and regional knowledge. Mainly quantitative data is used for analysis but also qualitative data is gathered from interviews to gain a better understanding of the health seeking behavior of the population in the area. Different approaches are used to model catchment areas within a GIS.

4.1 Study area

Since this research was motivated by questions that came up during a project in Rwanda it was clear that the study would take place there. In the following the selection of the study area will be described and then the study area itself will be introduced.

4.1.1 Selection of the area of interest

Rwanda has organized primary health care on the level of its 30 districts. To analyze the access to primary health care and to find an optimized way of estimating catchment areas for health centers for the whole country, Rwanda is, though small, diverse in terms of population densities and landscape. Therefore one district needed to be chosen that is not too special but represents more or less districts with a similar setting to make results transferable to other districts. To be able to take into account the effect of neighboring districts in all directions, a district needed to be chosen that is not bordering with another country. At the same time the city of Kigali is avoided as a neighbor to exclude its influence. Furthermore it was suggested to choose a mainly rural district that has also an urban area to analyze its influence on the utilization of surrounding health centers (KARENGERA, MOH, 2009). This limited the number of possible districts to two: Muhanga with the city of Gitarama and Huye with the university town Butare (see Figure 4.1).

Data from the Health Management Information System for 2008 (MOH, 2010d) aggregates the origin of patients, showing portions of patients coming from the zone that is assigned to the health center (“zone”, Z), patients coming from another health center zone (“hors zone”, HZ) and patients that are even coming from another district (“hors district”,

HD). The data is visualized in the GIS and used for the selection of the district. From this data a district with high differences of utilization shares, possibly with some extremes like 100% utilization from the zone in some areas and one or two outliers with high utilization rates from different zones or even other districts was to be found. The data at Huye District looked very promising to be interesting for further analysis: with outliers like Busoro-Gishamvu with only about 60 % or Kinyamakara with almost 100 % of patients coming from the assumed catchment area, it would be interesting to find explanations for those disparities. For three health centers a higher number of patients than the population which is estimated to be served is reported (MOH, 2010d; see Figure 4.2). This leads to questions like “How do utilization rates vary in detail?”; “Are single health centers more attractive to the population than others?”; “What does health centers make more attractive than others?” The Huye District was therefore chosen as study area for this survey.

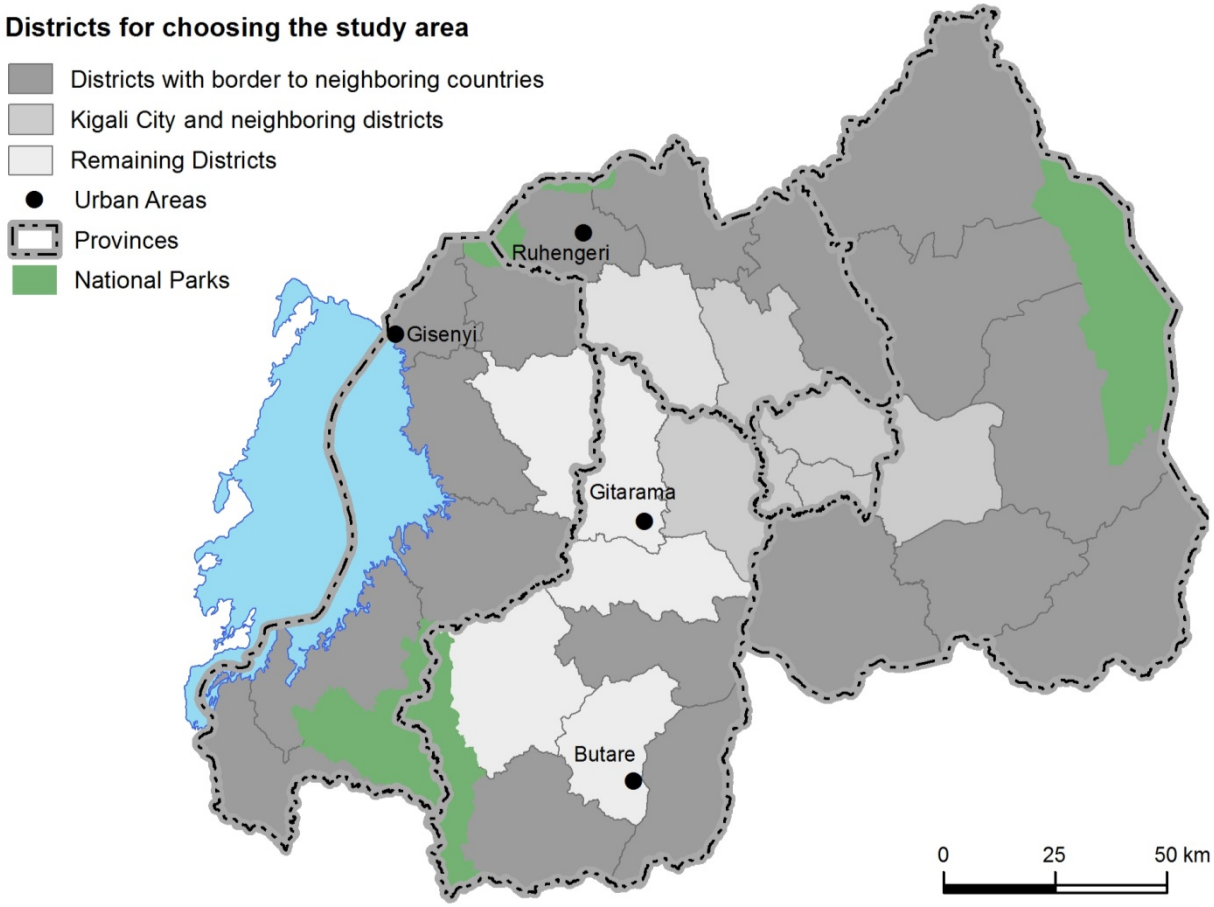

Figure 4.1: Districts of Rwanda with urban areas for selection of the study area

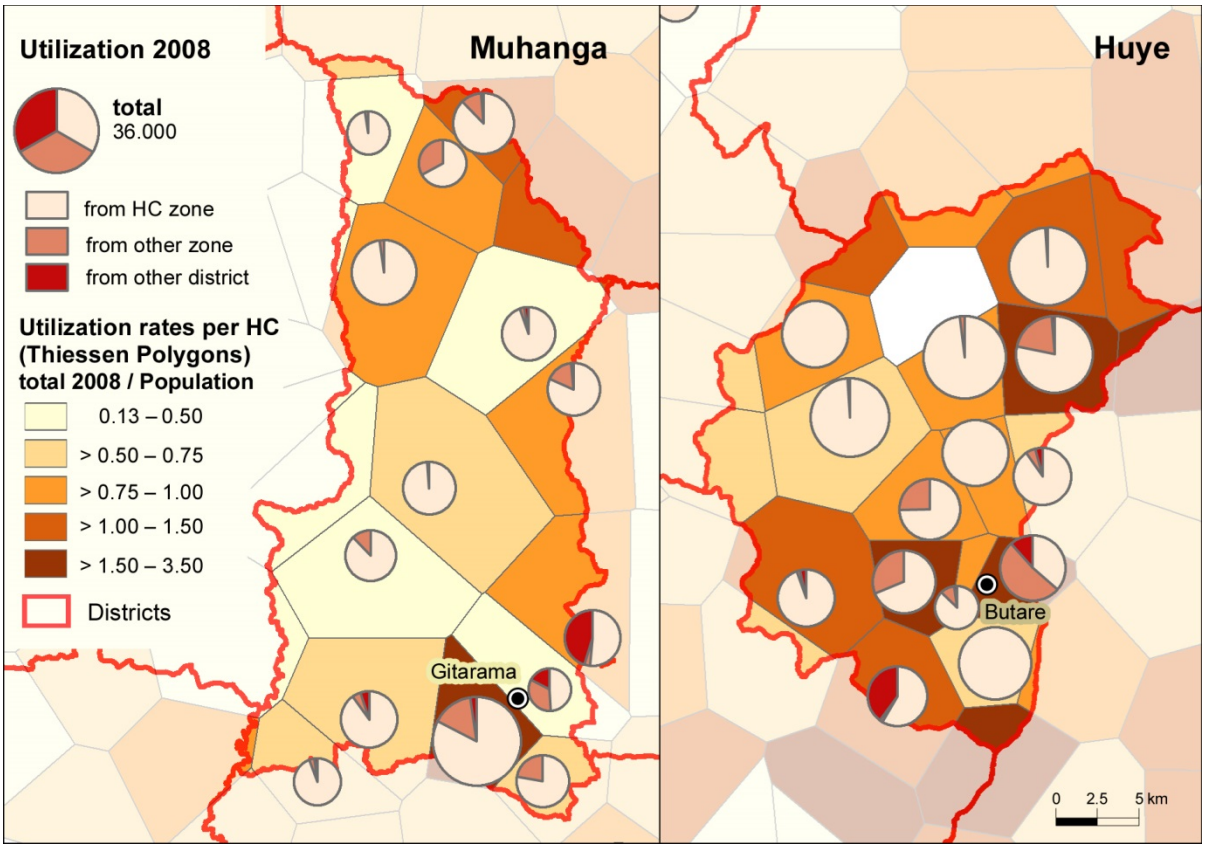

Figure 4.2: Closer look to the remaining districts Muhanga and Huye with utilization numbers of 2008. Utilization rates are calculated by the total number of patients of 2008 per officially reported population to be served at each health center.

4.1.2 Description of the study area

Huye District is a mainly rural area in the Southern Province of Rwanda with a size of 581.5 km². The population of 328,398 (by 2012; 2010: 318,000) is spread over 508 villages, about 20 % living in urban or peri-urban areas (2007: 26 %). Still about 90 % of the population is living mainly from subsistence farming while the majority of the young generation is unemployed (HUYE DISTRICT, 2007; NISR, 2012a; NISR, 2015). In 2012, almost 80 % of the population was under the age of 40, less than 4 % 65 years or older (see Figure 4.3). 25 % of the population is living in extreme poverty, another 21 % still considered as poor (NISR & MINECOFIN, 2012c). The illiteracy rate for the population of 15 years and older was estimated at about 42 %. The share of the female population lies for all of the 14 sectors between 50 and 60 %. Urban areas are found close to the city of Butare (Huye) with the former National University of Rwanda, the district hospital and the University Teaching Hospital (CHUB). The landscape is characterized by mostly cultivated land with small fields and smaller areas of woodland (HUYE DISTRICT, 2007; NISR, 2012a).

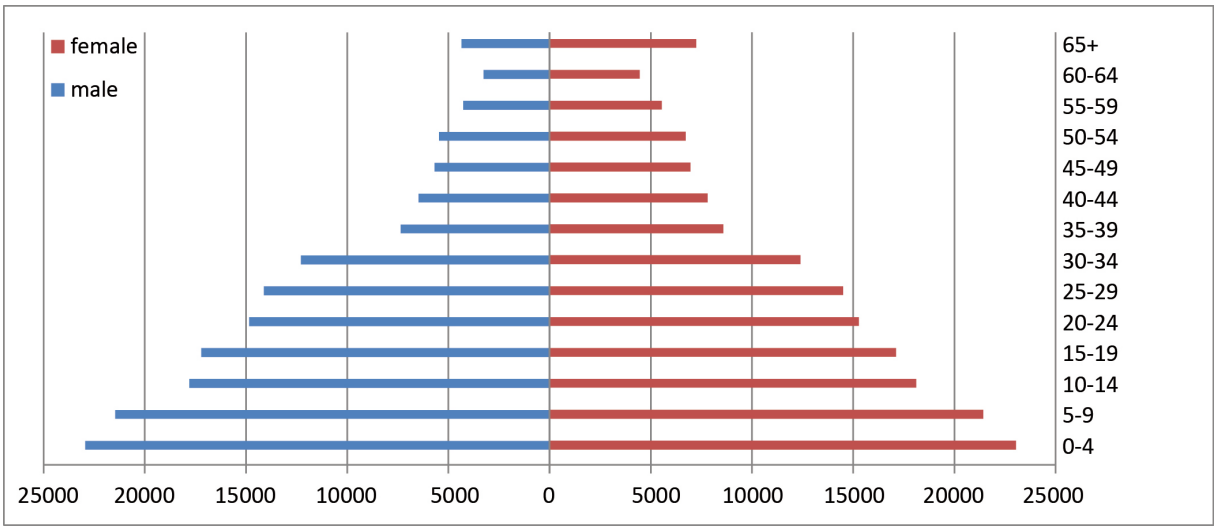

Figure 4.3: Population distribution over age groups for Huye district (NISR, 2015:6)

Lying in the central plateau of Rwanda, Huye District is generally hilly, descending to the northeast down to 1450 m and rising to the west to more than 2300 m of Huye mountain summit. The prevailing sub-equatorial temperate climate in Huye District results in an average temperature of around 20 °C. The annual rainfall is about 1160 mm which is comparable to the rest of the country (HUYE DISTRICT, 2007).

The water network in the Huye District comprises of various rivers and streams. Around them low-lying marshlands can be found which give possibilities for further development of the district. About 33 km² of the district area consist of swamps of which almost 60 % are drained (HUYE DISTRICT, 2007). Information is missing how far this water network is influencing the travel time of people.

Although the Huye District has a quite dense road network, almost only the national roads are paved. The other roads, even a big part of the district roads, are mainly dirt roads that can be difficult to drive during the rainy season (see Figure 4.4). In 2007, a big share of the roads was reported to be in a bad state, the same accounts for most of the bridges. This is also the reason why public transport is mainly not available in the rural areas of the district. Bigger busses are only available on tarred roads while small commuting busses are also using dirt roads to connect the districts, but also those are very limited. Especially in the urban area of Butare (Huye Town) also motorcycle taxis and bicycle taxis are available (HUYE DISTRICT, 2007). These factors build a strong barrier to the spatial accessibility of health care: travel distances to health centers are far and travel time increases significantly when travelled by foot (compare Table 2.1).

Figure 4.4:
District Road passing Matyazo HC

At the time of the survey in 2010, Huye District has 14 sectors with 14 health centers but not equally assigned (MOH, 2010b, 2010c; see Figure 4.5). 60 % of the population has health insurance with the majority being insured with Mutuelle de Santé (HUYE DISTRICT, 2011). The mean walking distance to a health center is reported with 45 minutes while 68 % of households are within one hour walking distance to the next health center (NISR &MINECOFIN, 2012). The district reported a geographical accessibility of health facilities of 91 % in 2011 (UWIZEYE, Huye District, 2011). To improve the spatial access there are furthermore six health posts, which can be seen as branches of health centers and that are serving the more remote areas (one of them was opened in September 2010, one was turned into a health center in 2011; UWIZEYE, Huye District, 2011). Information about these health posts and their role in primary health care was not given at the time of the survey. In the city of Butare (Huye) the district hospital Kabutare as well as the University Teaching Hospital (CHUB), one of the five national referral hospitals, can be found. Also one of the health centers is situated in the city center (CUSP Butare). Three of the health centers (Karama, Matyazo, and Simbi) are managed by religious communities and mainly sisters are working as nurses in these facilities. Also at Sovu HC mainly sisters are serving the people although it is not registered as an agreed facility like the others. The C-IMCI program was not yet implemented in Huye District. The community health workers received training in 2010 and started the program at village level in 2011 (UWIZEYE, Huye District, 2011). This study focusses on the utilization of health centers only that are public or are run by an agreed institution (religious).

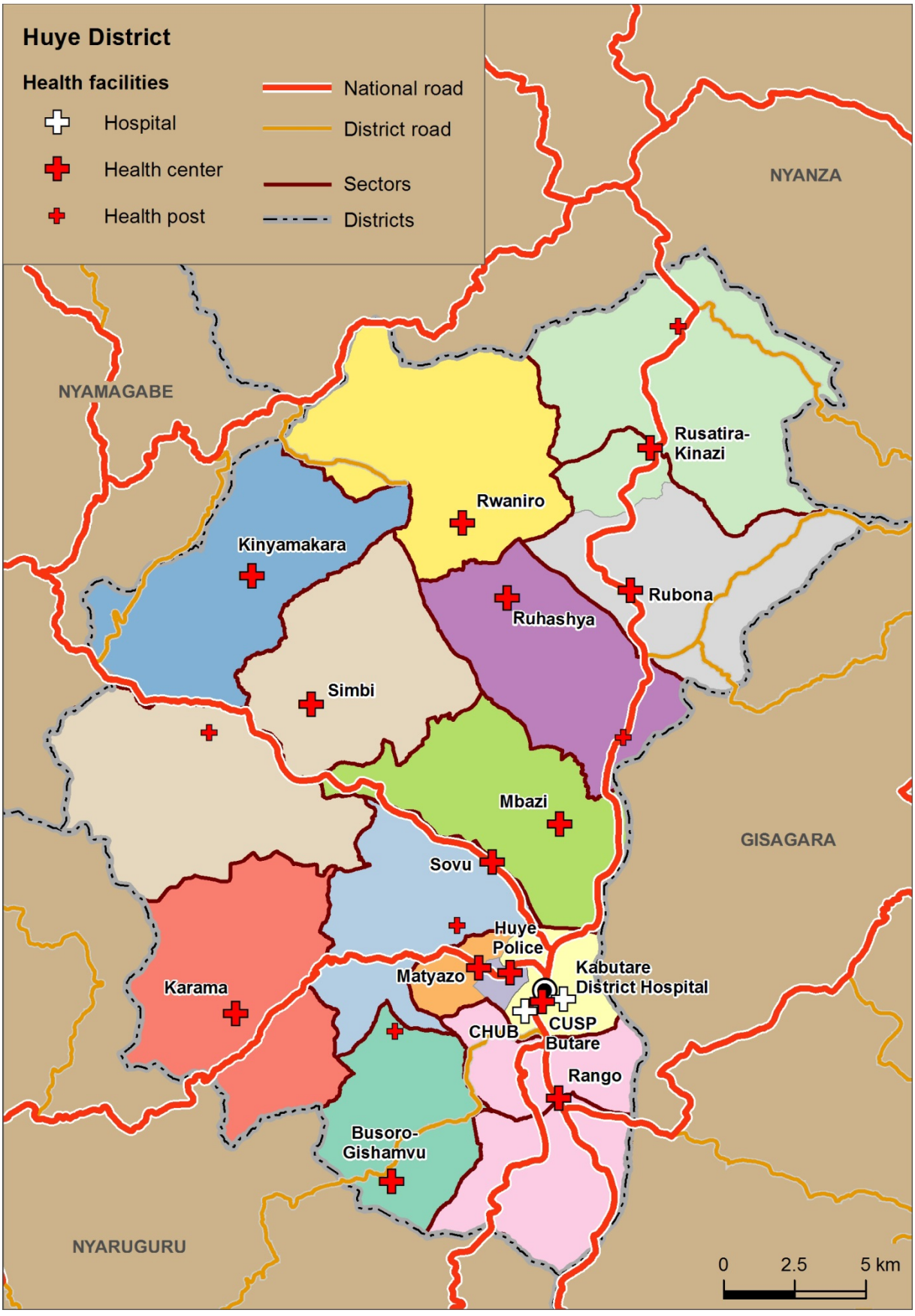

Figure 4.5: Huye District with its health facilities and health center areas (colored areas) by 2010

4.2 Concept of study methods

In the following, the study design used for the survey is presented. Primary and secondary data was used to collect information and to implement a geographical information system for further spatial analysis (see Figure 4.6). Primary data is gained by questionnaires filled with patients at health centers that build in combination with interviews with experts and group discussions with staff from health centers the basis for most of qualitative findings. Secondary data is mainly gathered from registration books while geodata is then used for spatial analysis and the modelling in GIS. Data from the HMIS of Rwanda gives information about total numbers of utilization while the census data of 2012 is used for the evaluation of the modeling results.

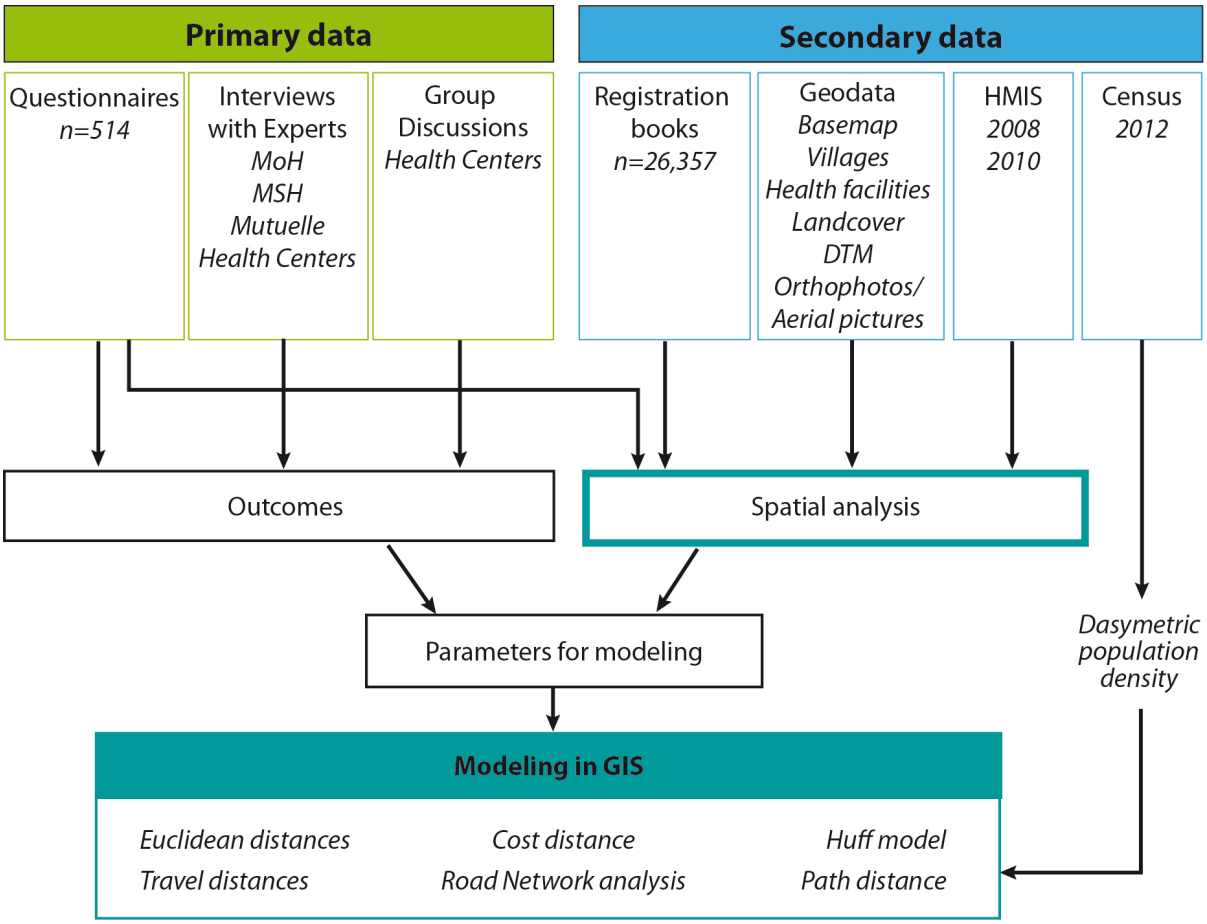

Figure 4.6: Study design

The original study design was approved by the Ethics Committee at the Ministry of Health Rwanda. For the approval, a study proposal has to be submitted and presented to the Ethics Committee (see Appendix I). The Ethics Committee discusses the proposal and gives recommendations or asks for changes. The improved proposal has to be submitted again to

the Committee and is then approved for one year. After the approval no changes are allowed. The commonly used pre-test could not be applied due to these requirements and was replaced by interviews with experts and training of interviewers.

4.2.1 Questionnaires at health centers

A questionnaire (see Appendix I-A) was used to collect information about the means and costs of transport, the patient's background as well as about their utilization of health care. This information is not yet available in detail for Rwanda.

The questionnaire consists of 24 main questions. The first eight questions concern demographic information as well as if the person interviewed is a patient or an accompanying person. This section also includes the level of education. The next part of the questionnaire, again eight questions, deals with the means, costs and time of travel to the health center while the remaining eight questions concern the visit of the actual health center and the behavior in seeking primary health care. The last question aimed to gain some knowledge about the reasons for choosing a certain health center. The questions are mainly formulated as closed questions. Three questions are aiming the interviewed person to answer in detail or to give further explications. Still, the person always has the possibility to give comments or to add an option ("else") to the given number of answers.

The questionnaire was developed based on other studies (ABEL-SMITH & RAWAL, 1992; BUOR, 2003; FIELD & BRIGGS, 2001; TANSER et al., 2006) and modified and evaluated with support from Rwandan experts with geography and GIS background. It was drafted in English and then translated into Kinyarwanda by a Rwandan student from the Geography Department at former NUR. The translation was reviewed again by a Rwandan geographer.

During a training in August 2013 four students from the former NUR, Geography Department, were briefed and trained in doing the interviews with the questionnaire. The training was conducted at CUSP HC in Butare on 16 randomly chosen patients during the regular opening time in the morning.

During a period of two weeks in September 2010 the survey team including the trained four students visited all health centers in Huye District to conduct the survey on patients at health centers. At each health center a mixed couple of two students was doing the interviews face-to-face with the patients based on the questionnaire. The researcher was

supervising the interviews for some time from the distance. Table 4.1 gives an overview about the date and the time the survey was conducted at each health center.

Concerning each health center and each day a total population survey was conducted. The research teams arrived in the morning at the health center where they interviewed each as many persons as possible, moving more or less through the line of patients waiting for their consultations (see Figure 4.7). The teams stayed always as long as there were no more patients left to be interviewed. Then they were waiting for at least 30 more minutes for later coming patients. Considering the data of 2008 for the scheduled time of the survey (September 1 to 9, 2010) at each health center 35 up to more than 100 patients per day have been expected. It was estimated that 40 to 60 patients could be interviewed per health center. Considering less frequently visited health centers the total was estimated with 500 filled questionnaires assuming a high response rate. With a total of 514 valid filled questionnaires the expectations have been fulfilled. The patients have been showing a very high acceptance of being interviewed: Only one patient refused to participate in the survey. Also visitors accompanying a patient have been interviewed, which concerned mainly mothers. For those also the age of the child has been recorded. For further analysis only respondents who were patients themselves or have been accompanying a child are taken into account which reduces the number of questionnaires to 476.

Figure 4.7:
Waiting area at Karama HC

Table 4.1: Fieldwork schedule – survey at health centers

Health Center (number of questionnaires/ considered for analysis)	Wed Sept 1	Thu Sept 2	Fri Sept 3	Mon Sept 6	Tue Sept 7	Wed Sept 8	Thu Sept 9	Fri Sept 10
Matyazo (33/31)	7:00–3:15							
Karama (34/26)	8:30–3:00							
Rango (51/48)		7:00–2:30						
Mbazi (49/45)			7:30–2:30					
Sovu (27/26)			7:45–3:00					
Rwaniro (22/21)				7:30 – 11:30				
Ruhashya (27/20)				7:45–12:00				
Huye Police (28/26)					7:30–1:30			
CUSP Butare (45/45)					7:00 – 2:00			
Rubona (46/42)						7:15–1:00		
Rusatira-Kinazi (43/40)						7:45–1:30		
Simbi (59/55)							7:15–1:30	
Kinyamakara (27/26)							8:00–12:00	
Busoro-Gishamvu (23/23)								8:00–12:00

Date and time of the survey at each health center, Team 1

Date and time of the survey at each health center, Team 2

After the patient arrived at the health center and was registered for treatment the interviewer informed him/her briefly about the survey (see introducing text on questionnaires, Appendix I-A) and asked him/her to participate. The patient was offered to do the interview in a separate room or in a silent place in or at the health center which was never claimed. At the beginning of all interviews, the students informed the participants of the purpose and nature of the study and its expected benefits. Participants have been made aware that, giving their consent by signature or thumb print, they agree to participate in the survey. The interviewers filled the questionnaires together with the patients. While the interviews were done in Kinyarwanda the answers were noted in English. Additionally the time of the interview was noted. The questionnaires were registered with an unique identification number composed of the initials of the interviewer and a running number.

During the survey time the inauguration of the president of Rwanda (September 1, 2010) took place as well as the end of Ramadan (September 10, 2010) which led to lower numbers of patients. Still the number of filled questionnaires did always meet the benchmark of 20. The influence by weather conditions which would not allow travelling long distances by foot was reduced by conducting the survey during the dry season. The day of survey at each health center was chosen randomly. To reduce travel time between the two health centers of one survey day, two health centers were chosen that are close together. On two days only one team was available for the survey.

4.2.2 Interviews with Experts

Interviews with different experts were conducted to gain more knowledge about Mutuelle de Santé and its utilization, about the situation in the Huye District concerning the health system and about the situation at different selected health centers. Furthermore different people at the Ministry of Health were interviewed to receive more general information about the health system and available data. The interviews are listed in the following in chronological order:

1. Stephen Karengera, Director of Policy Planning and Capacity Building Unit, Ministry of Health Rwanda, Kigali, November 9, 2009: informal interview in English; the main purpose of this interview was to find out if the Ministry of Health is interested in the study and if there are requirements or suggestions for conducting the survey; information about existing studies and available data was received.
2. Emilien Nkusi, HMIS, Ministry of Health Rwanda, Kigali, November 11, 2009: informal interview in English; gaining information about available data concerning the origin of patients for each health center.
3. Responsible persons at each health center, August 25 and 26, 2010: structured interview with four open questions, in English with help of interpreter; gaining information about infrastructure at health centers (number of rooms, beds) and information about higher utilization during the week and over the year.
4. Anja Fischer, GTZ, working with Mutuelle de Santé at this time, Kigali, September 13, 2010: structured interview with five open questions, in German; to gain knowledge about costs of Mutuelle de Santé for the population, registration regulations and patient roaming policies for Mutuelle de Santé.

5. Rissa Antoinette Ntakirutimana, Huye District, Mutuelle de Santé, Butare, April 6, 2011: structured interview with four leading questions, in English; to gather information about special characteristics of the Mutuelle de Santé in Huye District; furthermore data about registrations for Mutuelle de Santé in the Huye Districts was received (HUYE DISTRICT, 2011).
6. Randy Wilson, MSH in cooperation with MOH Rwanda, Kigali, August 1, 2011: informal interview in English; gaining information about Performance Based Funding (PBF) data available in Rwanda and general information about the Rwandan HMIS; updated list of health facilities received (MOH, 2012c).
7. Responsible persons at selected health centers (Japhet Najituriki, HC Busoro-Gishamvu; Cesaire, HC Rango; Sister Atanasie, HC Matyazo), August 31, 2011: structured interviews with eight open questions, in English; these interviews were done after first results of the survey were visualized; the main purpose was to gain information about offered services, the served population, availability of public transport in the area and the implementation of new strategies for the health sector.
8. Petronille Uwizeye, Huye District, Head of Health Unit, Gitarama, August 31, 2011: structured interview with fourteen mainly open questions, in English; recorded; main purpose of this interview was to discuss first findings of the survey and to receive answers to open questions revealed during the research of literature and during the survey.

4.2.3 Group discussions

To receive feedback and ideas about possible explanations for preliminary findings and to include the regional knowledge from health centers, the results of the survey were presented to the staff from health centers in a bigger group (December 9, 2013). The presentation took place following a meeting of health centers at the office of the Huye District Health Unit and was given in English because it was expected to have mainly the Heads of the health centers in the meeting. This was not the case and resulted in linguistic difficulties on side of some members of the audience. Still, questions could be answered with help of other people attending the meeting. In total about 30 people were present which was far more than expected.

With help of a short questionnaire (see Appendix II) every health center had the opportunity to give feedback to the presentation and to the results of the study. In this questionnaire the first six questions concerned the name of the health center and the responsible person attending the meeting. Four open questions were aiming to get information regards the awareness concerning the high/low utilization from other sectors and possible reasons as well as realized changes in the utilization over the last three years. Additionally there was space for comments. Since the provided copies of the questionnaire have not been enough for everyone it was tried to receive at least one questionnaire from each health center.

In total 13 questionnaires have been received, filled by 12 of the 14 health centers (see also Table 4.2). From Rango two questionnaires have been filled. CUSP and Sovu are missing. CUSP did not attend the meeting; Sovu joined the group later again. Due to the high fluctuation at health centers only six of the questioned persons were already working at their health center in 2010.

Table 4.2: Filled questionnaires by position of the answering person

Position	Number of filled questionnaires
Head of health center or assistant of Head	5
Nutritionist / in charge of Nutrition	4
Assistante Sociale	2
Nurse	1
Not named	1

In a small group with the attending responsible persons from Huye Police, Sovu, Matyazo and Mbazi details of the findings were discussed to include regional knowledge and experience of the staff at health centers. CUSP Butare was planned to participate in this discussion as well but did not attend the meeting. These health centers have been selected due to large overlapping areas or large areas that were supposed to be served by a certain health center but where the survey revealed high utilization of a different health center.

4.2.4 Registration books

For the evaluation of estimated catchment areas and to gain further knowledge about the actual utilization of health centers, detailed information about the actual origin of patients is needed. This data is not available in a digital way but is up to now manually

collected in registration books (see Figure 4.8). In those registration books the staff at the health center registers all patients coming for consultation with a running number of the day or the month; the name, the age, the sex of the patient; in some cases also the weight and the insurance number; his or her origin by village, cell, sector and district. The district is mainly only noted if it is not the Huye District. Furthermore they note if it is a new case or an old case and to which zone the patient can be assigned to (Z, HZ, HD). Also symptoms, diagnosis and treatment are noted.[3]

To access the needed information, data from registration books had to be digitized. All registration books available at each health center for the periods of March and July 2010 were photographically copied which led in total to about 4000 pictures. Only relevant data was entered into an Access database: an own id and the number of the picture; running number of the month or the year, respectively; date of the visit; age, sex and residence of the patient; if the consultation was concerning an old case or a new case; Z, HZ or HD. While for the half of the health centers the complete data was collected, for CUSP Butare data collection was stopped at 3660 entries, for the remaining a sample of about 1000 datasets seemed sufficient. This sample was taken by randomly choosing registration books which have been then completely registered until the number of about 1000 was reached (see Table 4.4). The sampling method leads most probably to a distortion of the results regarding utilization by month and regards the age of patients. In total 27,791 datasets have been registered, 27,536 of them new cases.

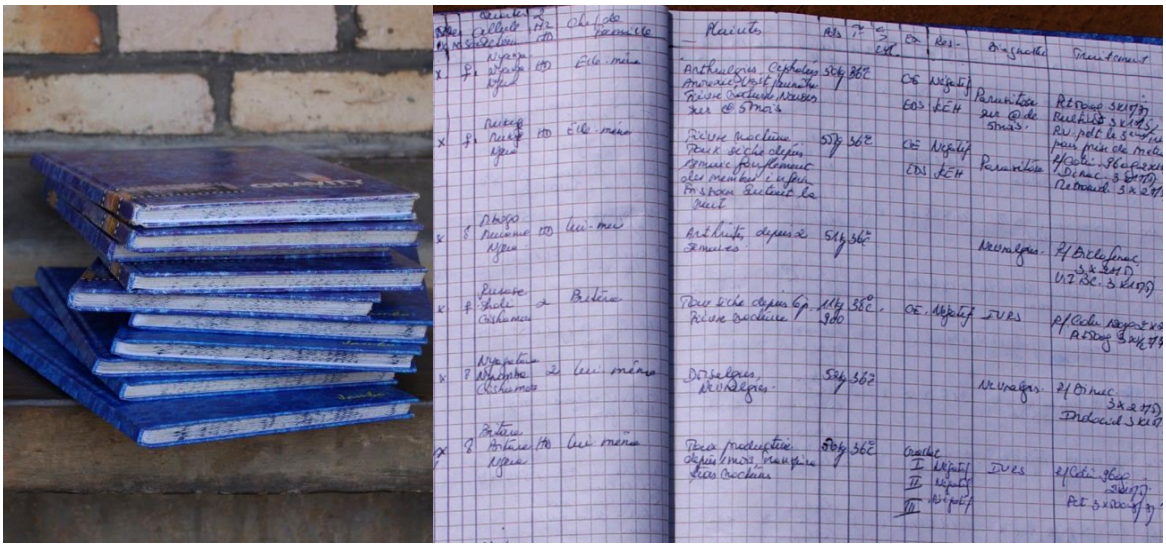

Figure 4.8: Registration books

[3] In the meanwhile health centers use official registration books and the zones are not reported anymore.

The biggest challenge occurred for registering the origin of the patients. In total for 1191 patients the village could not be registered due to following problems:

Table 4.3: Problems occurred registering the origin of patients

Problem	Number of cases
Village not mentioned	443 (20 % HD)
Village is named but cannot be identified through database	349
Village not readable	221
Village unconfidently assignable	173
Instead of Village the School is registered	5

The main share of entries have been difficult to read due to the fact that the registration books are filled by hand (see Figure 4.8). Further, differences in spelling of village, cell and sector names made it difficult to assign the correct village. In these cases the correct village could be found via the sector and/or cell and considering common spelling mistakes, like confusing r and l, and adding or removing of prefixes like Kabutare/Butare or Impinga/Mpinga. The registration form in Access showed pre-selections regarding the district, sector and cell which made it easier to find the assumingly correct village. A systematic error could not be identified but cannot be excluded in case of a systematic misinterpretation. In 26 cases village and cell or cell and sector have been written to the wrong column in the registration book; in 270 cases the village could be assigned via a different cell to the sector. This way, more than 26,300 datasets can be used for spatial analysis, 24,538 inside the study area. For further analysis only those entries are considered that concern new cases and that can be spatially assigned to a village (n=26,357).

For in total 363 cases (1.3 %) the allocation to Z, HZ or HD was either missing (69 cases mainly in CUSP Butare) or obviously wrong. In all cases the allocation was done or corrected according to the assigned village. Mainly patients were assigned incorrectly to the health center area (zone) instead of another area inside the district, in total 195 cases, most of them in Matyazo (103). Another 23 cases were even from another district. Despite the comparable high numbers of incorrect allocations at CUSP Butare and Matyazo there is no systematic error visible.

Table 4.4: Collected data that can be spatially assigned by health center, month and sex (differences in total are due to missing data on sex=115; only new cases) (* Health Centers with complete data collection)

	March		July		Total
Health Center	Female	Male	Female	Male	
Busoro-Gishamvu*	1077	669	453	238	2440
CUSP Butare	908	617	1111[4]	722	3363
Huye Police*	145	148	176	146	615
Karama	309	270	337	188	1126
Kinyamakara*	688	396	522	285	1893
Matyazo*	937	663	416	271	2287
Mbazi*	1646	831	696	325	3524
Rango*	1107	678	1018	493	3344
Rubona	394	310	255	215	1174
Ruhashya *	873	602	493	223	2197
Rusatira-Kinazi	328	223	349	217	1117
Rwaniro	313	204	295	159	972
Simbi	335	195	349	151	1031
Sovu	420	277	355	221	1274
Total	9480	6083	6825	3854	26357

For 74 cases the date could not be identified but they still can be assigned to the month of March 2010. They cannot be included into the analysis of day-dependent utilization of health centers though. In 115 cases the sex was not mentioned for the patient. Both cases do not affect the study due to its small number (0.3 and 0.4 % of 26,357). In 113 cases it was not possible to assign any age to the patient; 7 of those cases due to unreadable data. For 83 entries the age was registered through the age group assigned to the patient. In this case the upper end of the age class was registered. In 15 cases the age was registered with some doubt mainly due to bad handwriting. In one case the age was clearly readable but the column of the age group did not match. In registration books for about half of the patients the age was noted as the actual age of the patient, for the other half with the year of birth. Then the age was registered as the age by 2010. The age was always rounded to full years. Babies with six months or more have been recorded with the

[4] For one patient the village was found in the database but not in the geodata.

age of one year; the same applied to older children where the age was noted with digits in the registration book. The small number of problematic cases does not affect the analysis regarding the age of the patients.

Catchment areas are derived from maximum utilization numbers per village and health center, assigning those villages to the health center where at least 50 percent of the total number of patients per village were registered. For further calculations the catchment areas are simplified, neglecting exclaves and smoothing the shapes in areas where utilization was reported for different health centers. The simplified catchment areas are used to calculate the served population based on the village data.

Where spatial analysis involves also the surrounding area of Huye District, for more representative results the data is reduced to those patients who were coming from the Southern Province and for those patients not coming from Huye District the minimum was defined to be ten patients to come from one village to be included into further analysis (n=26,017).

4.2.5 Geodata

For the implementation of the GIS, data from the National Land Center (NLC, now Rwanda Natural Resources Authority – RNRA), the National Institute of Statistics (NISR, 2012b, 2012c) and the Ministry of Health (MOH) is used (see Table 4.5). Additionally land cover data and polygons of national parks in Rwanda were provided by the Center for Geographic Information Systems and Remote Sensing (CGIS) at the former National University of Rwanda (now University of Rwanda). All data was integrated in a personal geodatabase for ArcGIS 10, upgraded to 10.1.

A list of all *Imidugudu* (villages) by cell, sector and district with corresponding IDs is also provided by the NLC and used for the data entry in Access (NLC, 2010). Spatial data concerning health facilities in Rwanda was received from the Ministry of Health of Rwanda (MOH, 2010b, 2010c) and improved by personal field visits. The areas for health center zones are retrieved from the cells data set with help of information provided in the district (NLC, 2011; ANITA, Rubona HC, 2011; UWIZEYE, Huye District, 2011).

Table 4.5: Resources for spatial data

Source	Spatial data	By year
NLC/RNRA	– districts – sectors – cells – roads – rivers – point data for the digital elevation model in a resolution of 90 m	2011
NLC/RNRA	– Aerial photographs (25 x 25 cm) for the sectors Mbazi and Ruhashya – Orthophoto (2 x2 m) of the Huye District area	2008
NISR	– Villages: point data for the whole country, polygon data for the districts Huye, Nyamagabe, Nyanza, Gisagara, Nyaruguru – updated roads	2012
MOH	– Health facilities	2010
CGIS	– Land cover, national parks	(Received 2008)

Since minor trails are missing in the received data they are digitized manually from orthophotos with a focus on those trails that are likely to short cut the way to a health center from village points.

4.2.6 Data from the Health Management Information System

The Health Management Information System (HMIS) stores data from health centers that by the time of the survey was collected monthly by hand written forms on district level and then submitted to the Ministry of Health in Kigali where it was entered into the database. This data includes also information about health center utilization which was retrieved from the HMIS for this study for the years 2008 and 2010 (MOH, 2010d, 2011; NKUSI, MOH, 2009). The data contains information about the number of patients at each health center for each month, specifying old and new cases, as well as the percentage of patients coming from Z, HZ or even HD. This is the only available information about the origin of the patients attending the health center (NKUSI, MOH, 2009). The data from 2008 was used for defining the study area and to gain an understanding of spatial disparities in health center utilization. The data from 2010 was used to validate the survey data, comparing the collected data to official numbers from the HMIS (MOH, 2010d, 2011).

Since 2012 a new web-based solution is used that allows to enter the data directly at the health facility. Validation rules help avoiding errors which is reported to have increased data quality significantly (RUGUMIRE, 2013).

4.2.7 Census data

As the forth census, ten years after the last census, the most current one was conducted in Rwanda between August 16 and 30, 2012 (NISR, 2012a). It gives detailed information about the population of the country, mainly based on village level. The National Institute of Statistics of Rwanda (NISR) provided the provisional results of the census in terms of spatial data (polygons of villages for Huye and surrounding districts, centroid points of all villages in the country) including the total population for each village which totals in 307,558 inhabitants (NISR, 2012a). Further information is available in aggregated data on district or national level (NISR, 2012a; NISR & MINECOFIN, 2012b). The final result of 328,398 inhabitants for Huye District was not provided on village level (NISR, 2015). The population per village is used to develop a dasymetric population density map which is described in the next section.

4.2.8 Dasymetric population density map

To evaluate the different models and to compare for each result the served population per health center, the population is besides the size of the area the only available measure. The most accurate population data available was retrieved from census data of 2012 on village level provided by the NISR (NISR, 2012b; see section 4.2.7).

To be able to compare modelling results quantitatively, a dasymetric population map is developed since it distributes the population data more accurately over the study area (EICHER & BREWER, 2001; HUERTA MUNOZ & KÄLLESTÅL, 2012; MENNIS, 2003; SLEETER & GOULD, 2007:1). Especially in the context of access to health care when the served population is of particular interest, dasymetric mapping gives more realistic results for the distribution of a population. The here used method, the traditional limiting variable method was found to give the best result for EICHER & BREWER'S experiment (EICHER & BREWER, 2001; GALLEGO et al., 2011). For this method ancillary data is used to identify areas where people most probably not live. Land cover data used by HUERTA MUNOZ & KÄLLESTÅL (HUERTA MUNOZ & KÄLLESTÅL, 2012) was compared to orthophotos and found to be outdated and not detailed enough to be

useful for this study. Areas with obviously no population and areas with probably no population are instead digitized from orthophotos (NLC, 2008a, 2008b). This includes mainly rain-fed plantations, forests, and mountainous regions where no housing was visible in the pictures. The digitized data will be referred to as “landuse” in the following.

The digitized landuse data and the rivers dataset is transformed into raster files with a 30 x 30 m resolution (one ninth of the resolution of the DEM). Although rivers might not be that big the cell size is chosen in respect of those areas close to rivers/streams that are most probably not populated. This could be verified by orthophotos. Population densities based on village data are this way transferred into a grid showing the population per raster cell but only for populated areas. To compare the population per village with the dasymetric mapping a zonal statistic sums up the population per village. The quality assessment shows that only a very small and thus negligible error occurs during the calculations. The difference to the population provided by census data of 307,558 is with only 8 people below one per mill.

Taking the approach of HUERTA MUNOZ & KÄLLESTÅL (HUERTA MUNOZ & KÄLLESTÅL, 2012) into account, tests were performed, excluding also roads from population data. Also the resolution of 10 x 10 m was tested for better output. The results show only small differences for further analysis and thus is not worth the higher calculation effort.

4.2.9 Spatial analysis

Data from registration books and questionnaires is aggregated by village, visualized and analyzed in ArcGIS. Furthermore Village/Health Center relationships are established to be able to visualize and analyze the utilization by patients from the same village going to different health centers. Following objectives for analysis are defined:

a) Allocation of villages to health centers: Villages are assigned according to the main share of patients attending a certain health center (50 % or more). Differences per month and sex are to be revealed (or neglected). The allocation is used to define catchment areas of actual utilization which are used to evaluate the results of the modeling approaches.

b) Next available health center: From the origin of the patient (village point) the next available health center based on Euclidean and road network distances is calculated and compared to the actually used health center.

c) Distance to attended health center: From the origin of the patient (village point) the distance to the attended health center is calculated based on Euclidean and road network distances.

4.2.10 Modelling of catchment areas

Including qualitative and quantitative results from the survey at health centers, interviews and group discussions, different models for building catchment areas are tested in ArcGIS and evaluated with help of the catchment areas defined by the data retrieved from registration books and through the dasymetric population data (see sections 4.2.4 and 4.2.8). The main objective is to find the model that estimates most accurately actual catchment areas of health centers in Huye District. Testing of different approaches will also give evidence if models based on Euclidean or travel distance by road are suitable for the Rwandan context where the majority of the patients is traveling by foot.

Table 4.6: Overview of used methods

Method	Input data	Format input	Format result	Literature
Thiessen Polygons	Health centers	Vector (points)	Vector	NOOR ET AL., 2004
"Map of physical access"	Village points, health centers	Vector (points)	Raster	NOOR ET AL., 2004
Cost Distance Allocation	Roads, trails, rivers, health centers	Vector (lines, points)	Raster	TANSER ET AL., 2006
AccessMod	Roads, trails, rivers, land cover, DEM, health centers	Vector (lines, points)	Vector/raster	HUERTA MUNOZ & KÄLLESTÅL, 2012
Huff model	Health centers, village polygons	Vector (points, polygons)	Raster	FLATER, 2010; HUFF, 1964
Network Analysis	Roads, trails, health centers	Vector (lines, points)	Vector	(own approach)
DUI	Health centers, village points	Vector (lines, points)	Data	TANSER ET AL., 2001
Path Distance Allocation	Roads, trails, rivers, land cover, DEM, health centers	Vector (lines, points), Raster	Raster	TOBLER, 1993; HUERTA MUNOZ & KÄLLESTÅL, 2012; TANSER et al., 2006; NOOR et al., 2006 (own approach)

4.2.10.1 Euclidean distances

Thiessen polygons assign any point in the study area to its closest location, in this case health centers, based on Euclidean distances (ESRI, 2012a). For this study, Thiessen polygons are rendered for health centers in the study area. The served population per health center is calculated based on dasymetric population data. Based on the approach of NOOR et al. (2004) Euclidean distances from health centers to villages are calculated and interpolated with Inverse Distance Weighting (IDW) to result in a "map of physical access" covering the study area (NOOR et al., 2004). The population living within 5 km of the next health center is calculated (1) from the Near tool summarizing those villages with a distance smaller than 5 km and (2) using the interpolated areas, classified and transformed into polygons using again zonal statistics to calculate the population based on the dasymetric population density map.

4.2.10.2 Cost layer based approaches

For the cost layer different layers can be combined, for example roads, rivers, land use data. In general used data sets need to be transformed into raster grids, reclassified and can then be combined to one single layer, the cost layer. The analysis sums up the cost values going from one health center to each raster cell in the area. This is done for each health center. In the end, the analysis compares the cost result from each health center for each raster cell and this way assigns the health center that is reached with the lowest effort. The result of the analysis allocates areas to each health center where the "cost" is the lowest to reach the assigned health center (ESRI, 2012c). The simplified process is shown in Figure 4.9.

Following the approach of Tanser and his colleagues (TANSER et al., 2006:691) a cost layer with a resolution of 30 x 30 m is developed giving roads the average travel speed of 4 km per hour, trails 3 km per hour and the land in between 2 km per hour. Rivers are excluded from the data set by setting its values to *noData*. To give the result more meaningful numbers the values are recalculated into seconds per meter. All this data is combined to one cost layer and used for Cost Distance Allocation Analysis. The result shows for each location in the study area the total "cost" to reach a health center. From travel times the served population in a distance of one hour is calculated based on the dasymetric population map. Another result of the analysis are allocation areas that are assigned to health centers. Based on the dasymetric population the served population per health center is calculated.

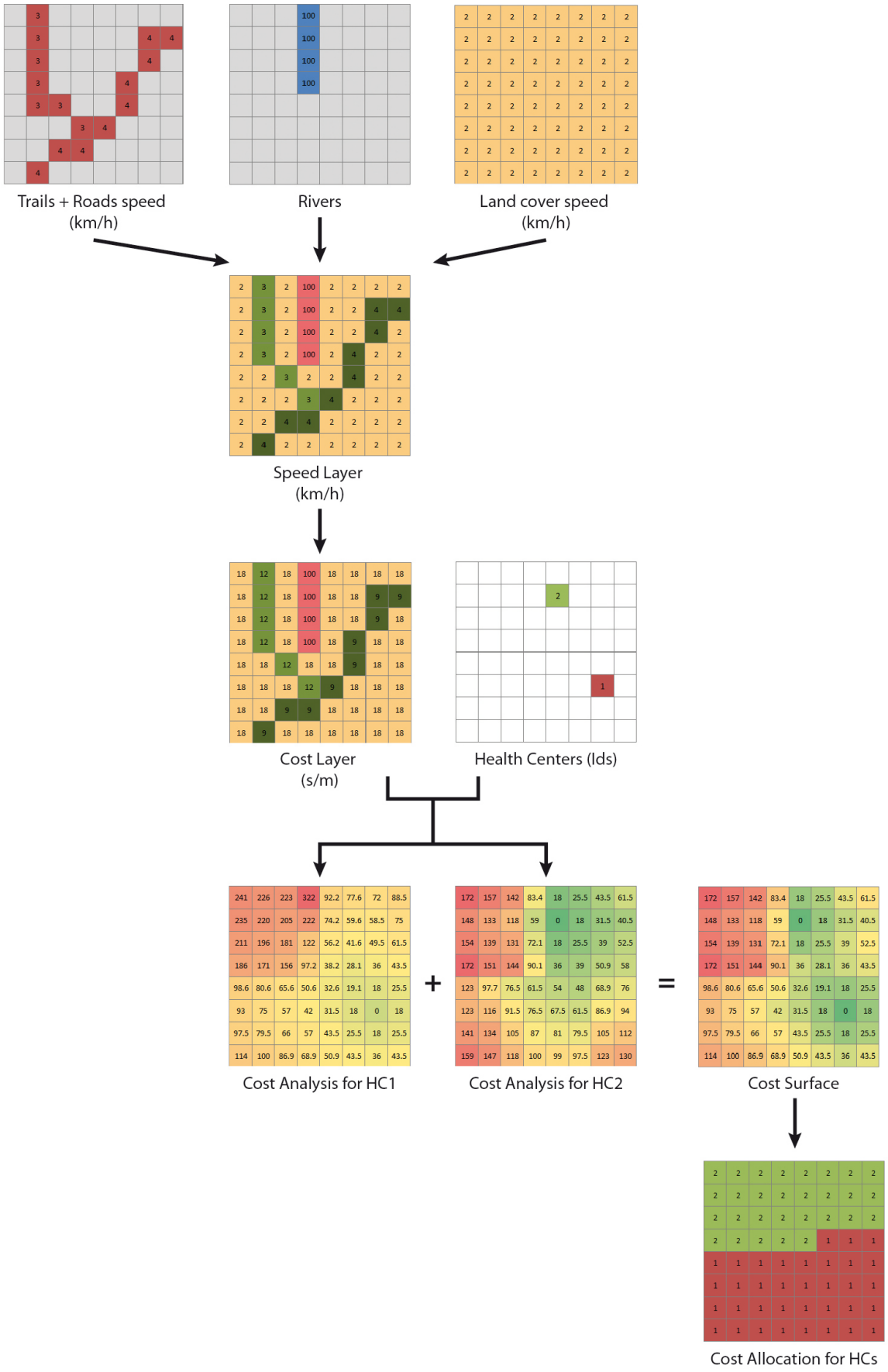

Figure 4.9: Schematic overview of the cost layer process for the path distance allocation analysis (own design based on ESRI, 2012c)

4.2.10.3 AccessMod Extension

Based on the approach of HUERTA MUNOZ & KÄLLESTÅL (2012:44) land cover data is reclassified and aggregated based on the Global Map of Accessibility project of the European Commission and equipped with the according travel speeds (EUROPEAN COMMISSION, 2010). The travel speeds are based on travel time by foot assuming an average travel speed of 5 km/h on footpaths or roads on level ground (TOBLER, 1993) and travel speeds between 1 and 5 km/h depending on the land cover. These speeds are defined in a "travel scenario table".

Travel speeds are applied to the ArcGIS extension AccessMod for ArcGIS 9.3 (HUERTA MUNOZ & KÄLLESTÅL, 2012; RAY & EBENER, 2008; RAY et al., 2012). The extension combines the land cover data with rivers and roads resulting in a grid where travel speeds are assigned according to the "travel scenario table". In the next step travel times from each grid cell to the next health center are calculated like in the cost distance analysis described before. In contrast to the cost distance analysis and comparable to the path distance allocation analysis (see section 4.2.10.8) this analysis is performed respecting the DEM in a resolution of 90 x 90 m. The results are used to calculate the served area as well as the served population in a travel distance of one hour.

4.2.10.4 Calculation of attractiveness factor

The Heads of health centers respectively the responsible person attending the meeting (see section 4.2.3), expressed their perception of a certain attractiveness of health centers that might be caused by:

- Public transport
- Customer care
- Distance
- Work
- Accessibility

(MUHARUGO, Matyazo HC, 2013; NGIRIMANA, Mbazi HC, 2013; NSABUMUREMYI, Huye Police HC, 2013)

The factors public transport, distance and accessibility can be aggregated to one factor called "Connectivity". Additionally distance should be considered in terms of distance from the health center to the next one. For the construction of an attractiveness factor for health centers following attributes are calculated for each health center:

- Total of street kilometers within a 2.5 km radius
- Distance to next health center

For each attribute the health centers are ranked: The highest value of total street kilometers, and the health center where the distance to the next health center is the highest, are ranked on first position. Accordingly for each attribute the health center with the lowest value is ranked on last position. The average ranking value is calculated from both attributes. This results into values between 5.5 and 12 for each health center (AF1). Visually the distance to another health center seems to have a higher influence. To take this into account it receives a higher impact (60 %) than the total of street kilometers (40 %). Here the values vary between 5.4 and 12.2 (AF2).

To be applied to spatial analysis both factors are recalculated to make in total 100 %. The attractiveness factor is added as attribute to the health centers and applied to the Huff model (see next section). It is also considered for the cost layer used in the path distance allocation analysis (see section 4.2.10.8).

4.2.10.5 Huff model

FLATER's "Huff model" Script Tool for ArcGIS is used to test the attractiveness factor (FLATER, 2010). The tool includes locations of facilities (stores) and their attractiveness as well as the origins of the consumers with an optional "sales potential" for example the population. Furthermore straight line or road travel distances can be used for analysis. The tool allows values between 1 and 3 for the distance decay parameter. In the original formula by HUFF (1964) the smaller the distance decay parameter is set, the further consumers can be assumed to be travelling. For the used tool the influence of this parameter is to be evaluated.

Five scenarios are tested for this tool:

(1) Straight line distance, distance decay parameter = 1, AF1
(2) Straight line distance, distance decay parameter = 3, AF1
(3) Road travel distance, distance decay parameter = 1, AF1
(4) Road travel distance, distance decay parameter = 3, AF1
(5) Straight line distance, distance decay parameter=3, AF2

Of the first four scenarios the best fitting result is chosen to test for the weighted attractiveness factor. Origins are set by village polygons.

The tool generates probability surfaces for each facility and from those market areas for all facilities in the defined study area. Market areas are assigned to village polygons which are aggregated and used for calculating the served population per health center.

4.2.10.6 Network Analysis

The Network Analyst in ArcGIS offers for example Service-Area-Analysis or Closest-Facility-Analysis. While the Service-Area-Analysis calculates the area that can be reached in a certain (travel) distance, the Closest-Facility-Analysis assigns the nearest health facility to given points (for example villages) and gives information about the travel distance (ESRI, 2012d; NYKIFORUK & FLAMAN, 2011:68).

On basis of the roads data set provided by the NISR (2012b) and digitized trails a network dataset is created with the parameters “connectivity at any vertex” and “global turns”. Two different settings have been considered for the Closest-Facility-Analysis: First, the area of Huye District with its health centers only; second, the area of Huye District but also taking health centers of neighboring districts into account. This analysis finds the closest facility by road network for each village. As Facilities the health centers of the district are loaded, the village points are added as Incidents. The output are routes specifying the closest facility and the distance via the road network. To give more realistic results single villages (in total 10) are shifted manually. The selection is done on basis of the landuse dataset digitized for the dasymetric population distribution map. Those village points are shifted to a more populated area within the village polygon based on orthophotos. Based on the closest facility assigned to villages, catchment areas are defined and the population is calculated on basis of the dasymetric population map.

The Service-Area-Analysis defines areas that are in a given travel distance to health centers. Here distances of 1000, 2000, 5000, 7500 and 10,000 m are used as break values. The areas of 5 km distance are used to calculate the served population based on the dasymetric population distribution map. Additionally the areas per health center are aggregated and used for calculation of the served population.

4.2.10.7 Utilization indices

Distance Utilization Indices (DUI) provide a measurement of spatial access (see TANSER et al., 2006; TANSER et al., 2001). Based on TANSER et al. (2001) exclusion error, inclusion error and the Distance Utilization Index have been calculated for health centers. The DUI is calculated with respect of Euclidean and road network distances. Furthermore for both alternatives the index is calculated with including only the patients coming from Huye District and in another calculation including also those patients coming from other districts. In contrast to TANSER's calculations, who used Thiessen polygons to estimate the catchment area of each clinic, the calculations here are based on the administratively assigned area for the health centers. Since the data for the utilization of health centers is not available for all homesteads, in this study the errors and indices are calculated based on the collected data from registration books. Following formulas are used for the calculation of Inclusion Error, Exclusion Error and DUI (TANSER et al., 2001):

$$Inclusion\ Error_{\mathrm{HCA}} = \frac{n_B}{n_A + n_B} \tag{4}$$

With n_A=number of patients living within the area of HC_A and n_B=number of patients living outside of the area of HC_A but using it.

$$Exclusion\ Error_{\mathrm{HCA}} = \frac{\mathrm{n_C}}{\mathrm{n_A + n_C}} \tag{5}$$

With n_A=number of patients living within the area of HC_A and n_C=number of patients using a different health center than the administratively assigned one (HC_A).

$$DUI_{HCA} = \frac{\sum_A Dist\ to\ HC}{\sum_A Dist\ to\ HC + \sum_B Dist\ to\ HC} \tag{6}$$

with

$$\sum_A Dist\ to\ HC = The\ sum\ of\ distances\ to\ HC_A\ from\ villages\ inside\ the\ area\ of\ HC_A\ for\ all\ patients\ using\ HC_A$$

and

$$\sum_B \boldsymbol{Dist\ to\ HC} = \boldsymbol{The\ sum\ of\ distances\ to\ HC_B\ from\ villages\ inside\ the\ area\ of\ HC_A\ for\ all\ patients\ using\ HC_B}$$

With utilization of the Network Analyst and the Near tool first the nearest health center is identified for each village in Huye District and straight line distances are stored with the village table. Secondly, with the Closest-Facility-Analysis, distances via the road and trail

network are determined as well as the closest facility considering the road network distance. IDs and distances for both analysis are stored within the village table.

For all health centers and all villages in Huye District, straight line distances and road network distances have been calculated with help of Network Analyst (OD Matrix) representing relationships. Also for villages in the remaining province with reported utilization of health centers in Huye District both distances have been determined.

To give a measure for spatial access an Euclidean Distance Index (EDI) and a Road Distance Index (RDI) are developed and calculated for each village. The EDI relates the Euclidean Distance (ED) from villages to the mainly used health center (MaxHC) to the ED from villages to the administratively assigned health center (AdminHC):

$$EDI = \frac{ED_{MaxHC}}{ED_{AdminHC}} \quad (7)$$

Similarly, the Road Distance Index (RDI) is calculated, taking the road distances (RD) via the network into account:

$$RDI = \frac{RD_{MaxHC}}{RD_{AdminHC}} \quad (8)$$

4.2.10.8 Own approach: Path Distance Allocation Analysis

In order to find the best fitting model, the approaches are combined and modified. This approach is based mainly on the studies of TANSER and colleagues (2006), and HUERTA MUNOZ & KÄLLESTÅL (2012). Two scenarios are performed within a path distance allocation analysis in ArcGIS: In respect of the prevailing travel mode of walking by foot the first scenario concentrates on walking speeds. The second scenario includes percentages of patients using other means of transport as reported during the data collection at health centers (see section 5.1.2.2 and Figure 4.10).

Roads, digitized trails, rivers, the former applied land cover data (see section 4.2.10.3) and landuse data used for dasymetric population mapping (see section 4.2.8) are transformed into grids of 90 x 90 m resolution (the same as the digital elevation model DEM) and combined to one data set giving travel speed values for each grid cell. The speed values are specified as seconds per meter to represent the best the needed effort to cross a grid cell. Travel speed for land cover data has been slightly modified compared to the study of

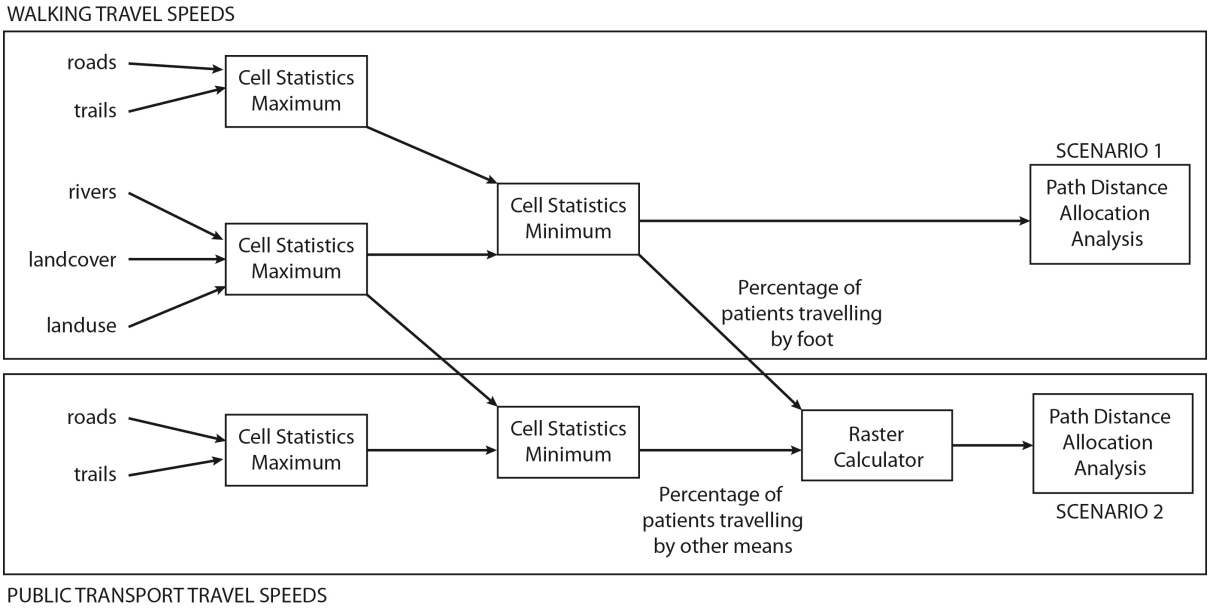

Figure 4.10: Schematic overview of scenarios for path distance allocation analysis

HUERTA MUNOZ & KÄLLESTÅL (2012): The maximum travel speed was reduced to 4 km/h and for those areas specified as "artificial" the travel speed was reduced to 3 km/h due to buildings that will hinder the crossing of the area. The rivers are considered as "small obstacles" but not as real barriers, giving an extra 30 minutes to cross a river, in this case simplified to crossing the cell (value=20); For the second scenario two cost layers are built: The first as for the first scenario, considering walking speeds; for the second cost layer travel speeds are assigned to national roads and district roads that assume that the patient is using a taxi (bus), other roads are assigned a slightly higher speed than walking speed taking the possibility of using a bicycle taxi for transport into account. The resulting cost layers give estimated travel times between 0.9 or 0.072 respectively and 3.6 seconds per meter and up to 20 for rivers respectively (see Table 4.7). To include the percentages of patients using public transport (see Figure 5.3) both values are applied to the administratively assigned areas of health centers and converted into raster files.

For the second scenario the cost layer for walking speed is multiplied by the percentages of patients travelling by foot and the cost layer calculated with travelling speeds adjusted to public transport usage is multiplied with the percentage of patients using other means of transport. Both results are combined to one final cost layer. Additionally the attractiveness factor (AF2) is applied to both scenarios. Here it is assigned to the administrative areas of health centers, converted into a raster layer and multiplied with the cost layers for each scenario.

Table 4.7: Travel scenarios for path distance allocation analysis

Landcover type	Walking scenario	Public transport scenario
Rivers	0.18	0.18
Open	4	4
Artificial	3	3
Cultivated/managed areas	1.67	1.67
Forest plantation/mixed with natural vegetation	1.25	1.25
Flooded Shrub	1	1
Forest plantation	1	1
National roads	4	50
Districts roads	4	20
Other roads	4	5
Trails	4	4

In contrast to the Cost Distance Analysis, TANSER and his colleagues (2006) were using, the Path Distance Analysis allows to include the DEM into the analysis and to use a vertical factor to respect the hilly terrain. This way the DEM is used for the surface which serves as basis to calculate the surface distance. The analysis is similar to the one used in the AccessMod extension. While there TOBLER's formula (TOBLER, 1993)

$$W = 6^{\{-3.5 \times |S + 0.05|\}} \quad (9)$$

where W is the walking speed and S the slope is used as vertical factor, now it is applied in a modified form. For slope values between -10° and 6° the constant speed of 4 km/h was used, above 6° slope the formula is adjusted to

$$\mathrm{W} = 7^{\{-3.5 \times |\mathrm{S} + 0.05|\}} \quad (10)$$

assuming first, that – especially for sick people on their way to a health center – a walking speed of maximum 4 km/h is more adequate in the Rwandan context, and secondly, that the walking speed is kept constant for a slight slope. The benchmarks for the decrease of speed are specified after comparing different formulas (see section 2.3.5). While the speed for descending is kept as specified by TOBLER, the speed for ascending is estimated to be slightly higher but still below the descending speed at the same slope (see Figure 4.11).

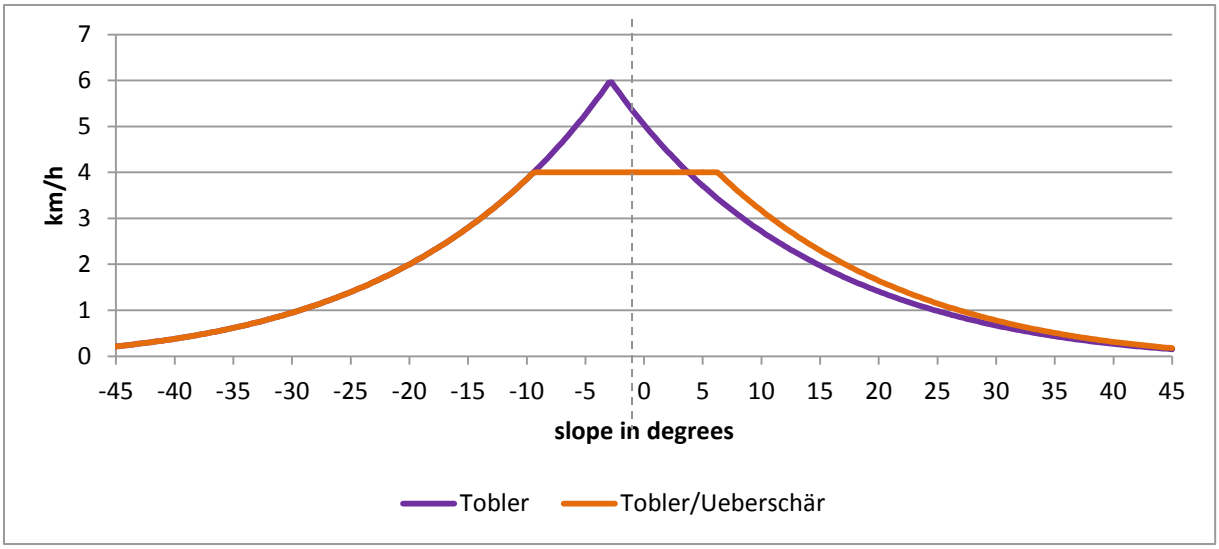

Figure 4.11: Adjusted speed per slope in degrees based on TOBLER (1993)

The speed values per 0.25 degrees steps for the slope were calculated in Excel and transformed into a factor with

$$\mathrm{VF_x} = \frac{\mathrm{W_{S0}}}{\mathrm{W_{Sx}}} \tag{11}$$

where VF_x is the vertical factor at degree value *x*, W_{S0} is the speed where the slope equals 0 and W_{Sx} the calculated walking speed at the degree value *x*. The table with degrees and factor values is included as vertical factor into the tool. The DEM is again used as vertical raster source where it serves as basis for calculating the slope between two raster cells. The Path Distance Allocation Analysis tool is executed with each cost layer as input costs. In both cases the health centers for Huye District represent the feature source data.

For both scenarios the allocation raster is converted into polygons which makes it easier to compare the results visually and zonal statistics are performed to calculate the served population per health center area on basis of the dasymetric population density map. Additionally the resulting distance raster can be interpreted as travel time. It is reclassified in 30 minutes ranges and again zonal statistics is performed to calculate the served population for each travel time zone.

5 Results: Evaluation and Discussion

5.1 Questionnaires at health centers

Questionnaires have been filled with 514 persons. In 65 % of the cases the questioned person was the patient; about 27 % have been accompanying their children. In a few cases parents have been seeking health care themselves while accompanying also a sick child (6 cases/1.2 %; see Figure 5.1). Comparable low was the share of patients in Karama and Rwaniro with only 50 %. Correspondingly, in Rwaniro the share of parents accompanying their children has been the highest with 41 %, while at CUSP this fraction is only 16 %. For further analysis only patients and parents accompanying their child will be taken into account. In the following all questioned persons will be referred to as patients.

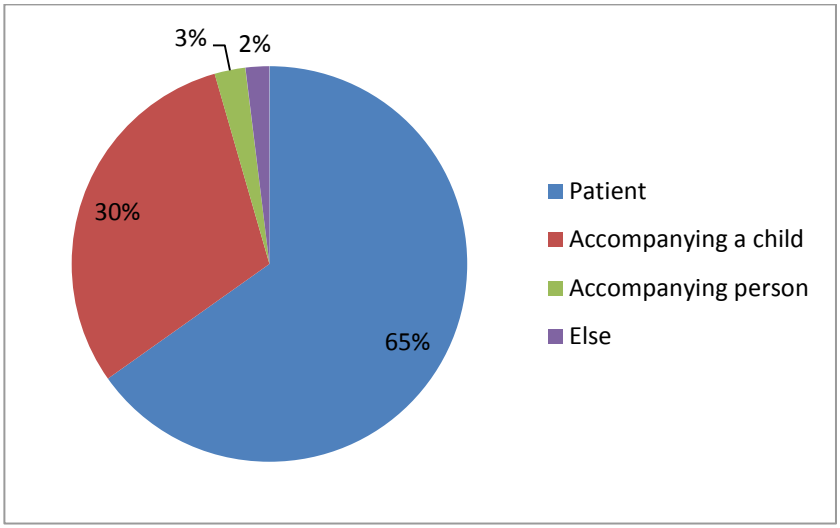

Figure 5.1: Status of the interviewed person

5.1.1 Validation of questionnaires

The full number of 514 (=n) questionnaires can be seen as valid although in some cases answers are missing or are not consistent. In case of parents/mothers who were accompanying their children, the questions regarding the demographic information and level of education have been answered in behalf of interviewed person, though the age of the concerned child has been reported as well.

The travel mode was validated against the travel time reported for each travel mode. Inconsistencies were recognized mainly due to incomplete answers regarding the travel mode. This concerns mainly patients who have been reported to have been using only public transport but reported then also walking time (27 cases), another ten cases reported to have

been coming by foot but reported also travel time by public transport, and only a few cases were found where other means of transport but only walking time were reported.

Where the reported travel time total did not match the for each travel mode reported travel time the total travel time was set to the sum of the reported values. The reported travel time does not correlate with the reported travel distance which shows the low validity of this information. Also calculations with Euclidean and road network distances retrieved from the GIS show only very low levels of a positive correlation. This was validated for patients coming from home only but also here correlations are still negligible.

During the training some challenges regarding the understanding and meaning of questions could be solved; problems with the last question were revealed only after the first days of survey. Although the wording was checked twice by local experts the last question has not been translated well and has not been well understood by the interviewers. The Rwandan wording means “At what level do you agree with these sentences?” (Question 24: How true are the following statements regarding your decision for coming to this health center today?).

It has to be kept in mind that the interviews were conducted in Kinyarwanda but the answers noted by the interviewers in English. This can distort the original intention of the answer due to misinterpretation and/or translation issues on side of the interviewer.

5.1.2 Descriptive Statistics

5.1.2.1 Demography and schooling

77 % (365 cases) of the questioned persons were female. The most balanced ratio can be found in Matyazo (56 % female/44 % male) while in Mbazi the share of female participants was with almost 90 % very high. The age of the ladies is well distributed though almost all age groups which makes it difficult to find an explanation for this high share of women. While the highest share among the male patients is found at the age between 20 and 24, babies and little children under five years make almost 30 % of the female patients. The latter might be caused by a misunderstanding while filling the questionnaire: Probably not the sex of the baby was reported in this case but the sex of the accompanying person. It can be assumed that mainly mothers are coming to seek for health care for their babies. The reason for the relative high share of male patients at the age between 10 and 40 can only be

guessed. Young men between 20 and 24 years are reported in slightly higher numbers at the health centers of Huye Police and Rusatira-Kinazi (in the following named Rusatira only). The majority of them are students, in Rusatira coming mainly from school. A possible explanation thus would be that they have been sent from school to attend the health center.

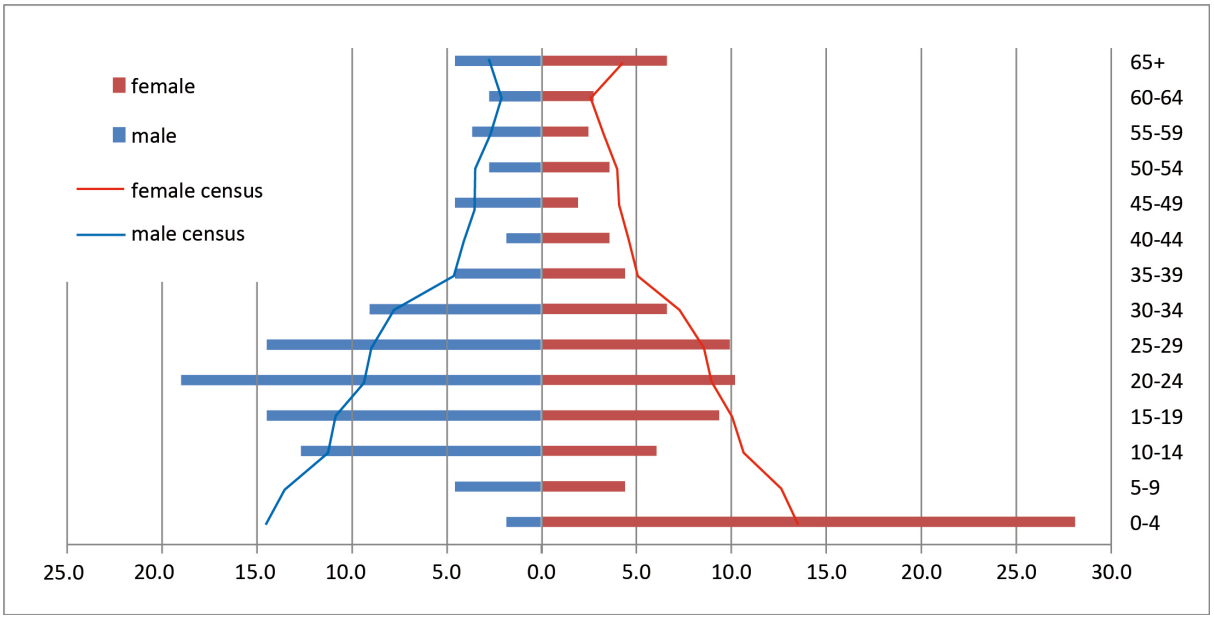

Figure 5.2: Percentage of the patients' age groups by sex in comparison to district average percentages (census; source: NISR, 2015)

In total almost 70 % answered to be farmers, almost 20 % were students, about 6 % were working in different jobs (hair dresser, driver, security, tailor etc.), 2.3 % were jobless. The share of farmers is the highest in Sovu and Simbi with almost 90 % while in CUSP only 40 % reported to be farmers. In Kinyamakara the share of students has been the highest with 31 % and the lowest in Ruhashya with no reported student.

85 % answered to have attended a school in their live. 100 % of the patients in Huye Police said so, while in Karama, Kinyamakara, and Sovu only 73 % visited a school. 86 persons (18 %) did not want to answer the question which level of school they have visited. Only two of the patients under the age of 20 reported to have never attended a school. For the patients older than 20 years, 53 % of those who visited a school at least finished primary school. In total, almost 80 % of the patients with the age of 15 years or older are able to read, only about 67 % in Kinyamakara but 96 % in Huye Police which is for the majority of the health centers much better than the national literacy rate of 71 % (THE WORLD BANK, 2013a).

5.1.2.2 Travelling to the health center

People were coming mainly from home to visit the health center (almost 90 %, in Huye Police, Ruhashya, Rwaniro and Simbi even 100 %), almost 10 % (half of the students) were coming from school, the most in Kinyamakara with 24 %. At CUSP in Butare 9 % came from work while for the other health centers this number is negligible. 84 % came by foot only (in Busoro-Gishamvu and Karama even 100 %). This verifies the assumption that most of the people are travelling by foot to reach a health center. Nevertheless about 5 % came by bus ("taxi") to the health center, another 5 % used a bicycle (either an own bicycle or as taxi) partially in combination with other means of transport. Remarkable high with 11 cases (about 26 %) is the number of people coming by taxi (bus) or other public transport (another 11 cases) to the health center in Rubona which totals in more than 50 % of the patients using public transport. This is followed by CUSP (Butare) where in total 40 % came by public transport partially in combination with walking a certain distance. At half of the health centers at least 10 % of the patients reported to have been using other means of travelling than walking to reach the health center (see Figure 5.3). This is highly related to proximity to a paved road (Rubona, CUSP, Rango, Rusatira) or a district road (Matyazo, Huye Police). According to the in general limited utilization of public transport also the reported costs for transport are low. Only 13 % of the patients had to pay up to 500 RWF to reach the health center, only single cases in Rubona and Rusatira reported costs of more than 1,000 RWF.

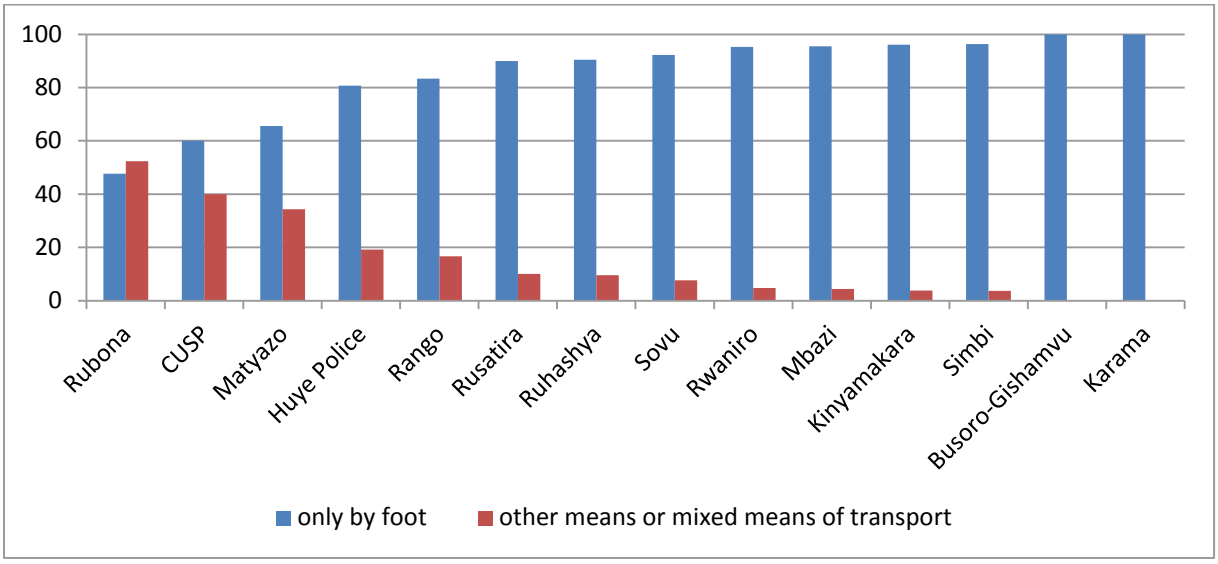

Figure 5.3: Percentages of patients by means of travelling

Two examples shall be given here for patients who used mixed means of transport:

A male, 37 years old patient travelled 28 km from Nyaruguru District to attend CUSP HC. He had spent one hour to wait for public transport and then travelled three hours by bus.

[CUSP, IG58]

Another male patient, 24 years, travelled about 20 km from Maraba Sector also for attending CUSP HC. It took him more than two hours to reach the main road where he waited 30 minutes for public transport to travel another 40 minutes. The distance walked can be estimated from the GIS with about 6 km. Both patients reported weakness which can be an explanation for an average walking speed of less than 3 km/h in the second case.

[CUSP, MW62]

Almost 92 % said that they could use the same trail coming to the health center during the rainy season; another 2.5 % said it's possible but difficult. This is mainly for the health center in Simbi the case. The necessity to use a different trail was reported by patients at health centers in Karama, (2), Mbazi (3), Rango (9), Rubona (1), Ruhashya (3), Rwaniro (1), Simbi (2) and Sovu (3), in total 5 % of the patients. Compared to a study in rural Ghana (MURAWSKI & CHURCH, 2009:102) this gives the impression that the rainy season does not limit the spatial accessibility of health centers as much as expected, still it obviously has an impact as patients report:

"Another reason to come is that the path we use to go to Matyazo HC is not good especially in the rainy season. So sometimes we change and come to this Police HC." *[Huye Police, KB107]*

"I used to pass in the short cut but when it's in the rainy season I pass on the main road which is too far." *[Ruhashya, KB73]*

149 patients (about 30 %) did not want to estimate the distance they travelled to the health center. From the remaining patients about 90 % estimated a travel distance of up to 5 km, less than 4 % estimated a travel distance of more than 10 km (n=327). In general the travel time seems to be more reliable than estimated distances, still the reported travel time does not correlate with measured travel distances, neither Euclidean nor road network distances. A small correlation can be found between travel time by other means than travelling by foot and road network distances (=0.4). About 47 % of the patients reported to need up to 30 minutes to reach the health center, about 23 % needed more than an hour. In Simbi almost half of the patients (44 %) reported to have been travelling more than one

hour, also for Karama, Rango, and Rwaniro the share was more than 30 %. For CUSP and Ruhashya more than 90 % reported to have been travelling only up to one hour.

For analysis the reported travel time has been cleaned from waiting time and time spent stopping on the way, as far as it has been mentioned during the interview. The average travel time by health center is between 39 (Huye Police) and 89 minutes (Rwaniro). This variation seems to be likely in relation to the different size of the catchment areas. But relating the average travel time to the size of the administrative catchment areas of health centers, patients of Huye Police, Matyazo and CUSP Butare seem to accept longer travel times to reach their health center (see Figure 5.4). Although there is no connection between longer travel times and utilization from other areas than the assigned health center visible, the map in Figure 5.15 shows especially for these three health centers the extended utilization from other areas, while the map in Figure 5.5 does not show a pattern regarding lower or higher average travel time values.

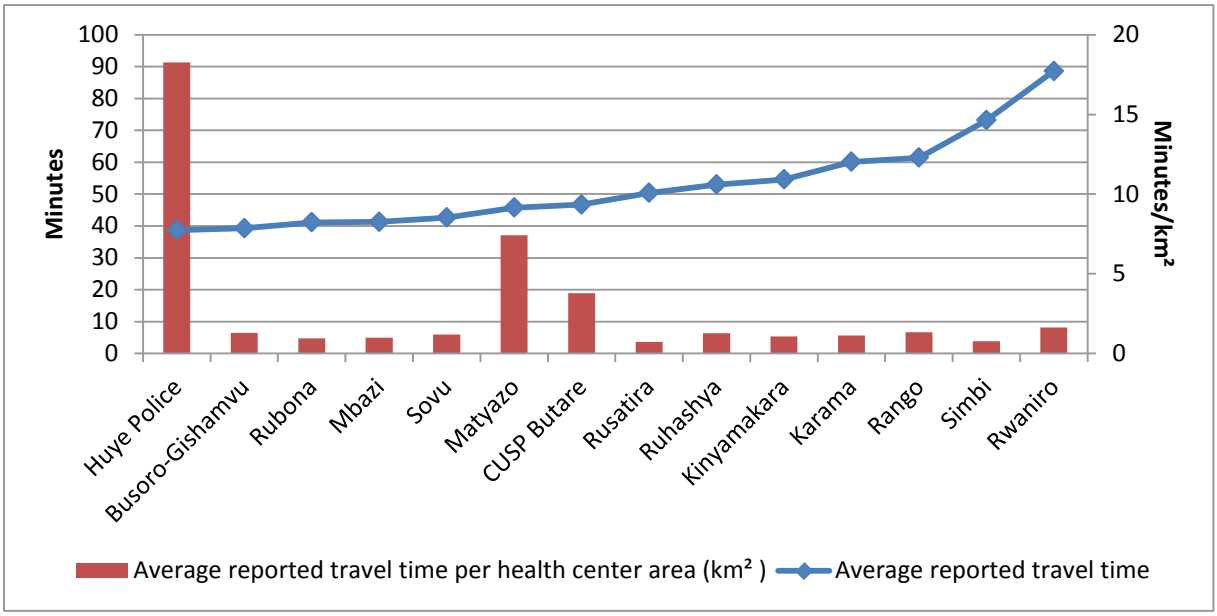

Figure 5.4: Average reported travel time by health center (cleaned values)

Patients travelling for more than two hours have all reported to have been walking all the way, except of one person. But even short distances are perceived as exhausting as for example a young mother reports who needed one hour to reach the health center in only one kilometer distance:

> *"This health center is the nearest but still there's a long distance… with my child on the back …. Aah it's not easy at all, nothing else to do."* *[Rango, KB19]*

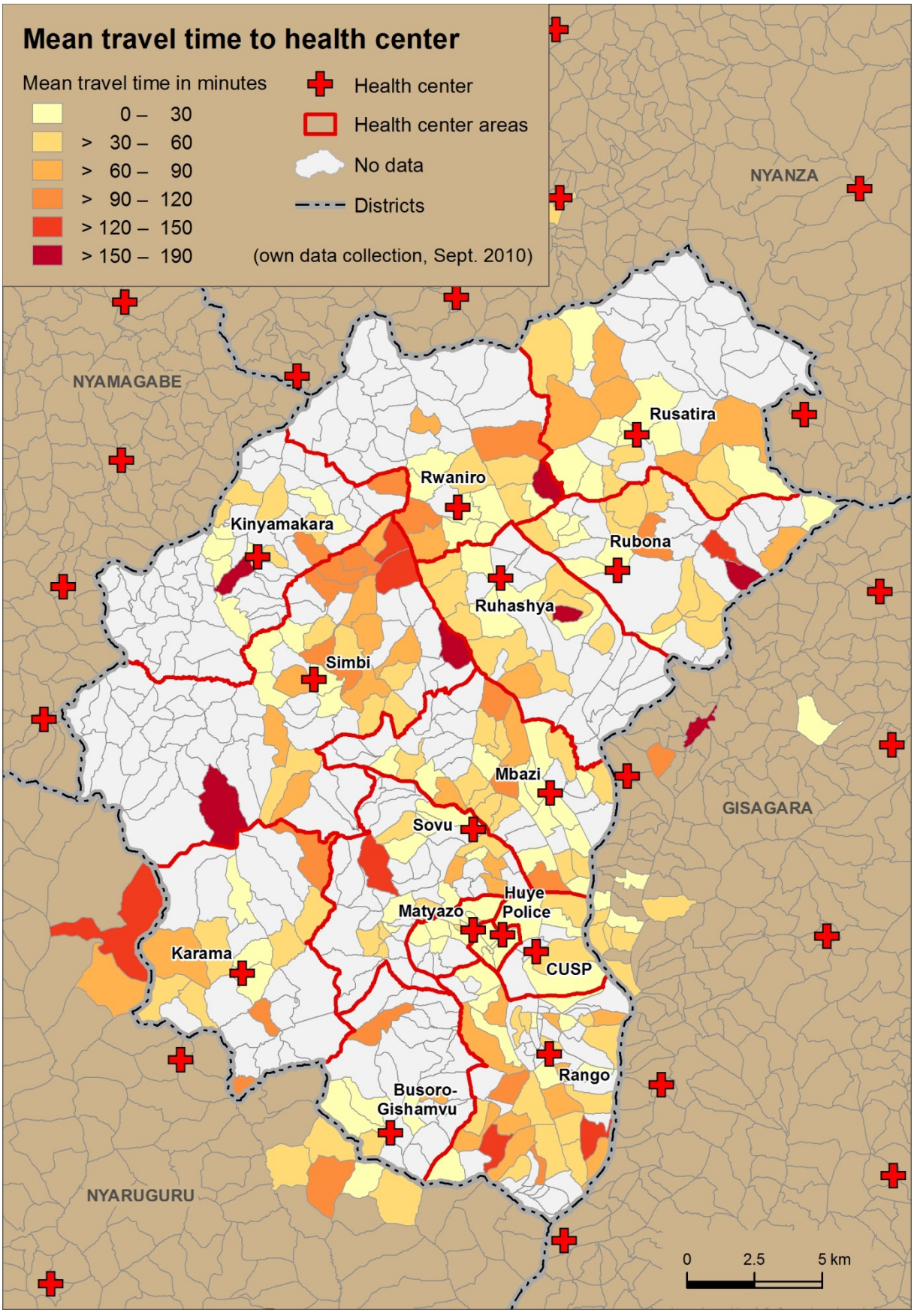

Figure 5.5: Mean reported travel time from villages to health centers

5.1.2.3 Utilization of health centers

While at Huye Police HC a high number of 23 % of the patients have been insured with RAMA, also 9 % reported to have no health insurance at all. In total this is for 2 % of the patients the case. Patients at Busoro-Gishamvu, Karama, Kinyamakara, Matyazo, Simbi and Sovu reported to 100 % to be insured with the Mutuelle de Santé. With 8 % the share of patients being insured with FARG was the highest at Mbazi HC.

In total 78 % of the questioned persons answered to be at the health center due to acute symptoms or urgent help needed. In Kinyamakara this is applicable for 100 % of the patients, in Ruhashya for only 48 %. In Busoro-Gishamvu, Karama, Matyazo, Mbazi, and Ruhashya the share of patients coming for regular treatment has been between 19 and 27 %.

Seeking for primary health care patients consider the most going to a health center but also a lot of patients would go directly to a pharmacy or ask the community health worker or local health advisor for help. While none of the patients in Karama considered going to a pharmacy, in Matyazo, Rwaniro and Sovu it did not seem to be an option to seek care with a local health advisor. Only in Rango and Simbi this option was mentioned by a high number of patients. This might be due to the just starting implementation of the community health worker program in Huye district at this time. In total only about 3 % mentioned to use traditional medicine, either treating themselves or receiving treatment by a traditional healer or other family members. The highest rate was found in Rwaniro, where 14 % of the patients reported to make use of traditional medicine for first treatment. But only about 2 % of the asked persons reported to have seen a traditional healer before visiting a health center because of the actual illness. Those can be seen as single cases with no visible spatial pattern. The knowledge of possibilities for seeking health care does not seem to be dependent on the level of education (Chi-Quadrat Test).

It can be assumed that patients who visit the health center are more unlikely to trust in traditional medicine which explains the low number of its utilization. But mainly it will be the fact that traditional healers were banned by law from practicing which forces the population to look for other providers for primary health care:

> *“She used to go to the traditional healers from her childhood until recently in 1996, but now she does not go there because it's prohibited.”* *[Karama, KB10]*

For all health centers in the district 38 % of the patients have been seeing a health center for treatment of the current illness for the first time. While in Simbi this was the case for 67 % of the patients, in Matyazo it was only true for 9 % of the patients. In total about 60 patients said to have been returning many times. Of all patients who have been seeking for treatment more than the current time (n=261) 78 % have been at the same health center before.

It can be observed that the patients have a higher opinion of health centers and hospitals in Butare (Kabutare, CHUB, CUSP, “HC in Butare”, “Hospitals in Butare Town”, “Butare Town”). 95 times those have been put on the first position, 75 persons named one of those on second or third position. About 75 % of the patients saying so were at another health center at the time of the survey. Also the health center in Butare, CUSP, receives 40 % of the first position rankings from patients of other health centers. In 57 % of the answers the health center on first position is also the health center where the interview was carried out (271 of 438). If there was given a health center on last position it was always the health center where the interview took place (23 cases). Some said (in Rusatira and at CUSP), “all health centers are the same”. Patients in Rwaniro put their health center the most on the first position (95 %) plus the remaining only on the second position, while in Busoro-Gishamvu the health center was ranked also by 22 % of the patients on third and 13 % on last position. Also Rubona still has 95 % of the patients ranking it on first or second position. In general the place of the survey was most likely to be ranked as first position. Exceptions are Busoro-Gishamvu and Mbazi, where also hospitals in Butare are often ranked on first position.

Some interview partners had difficulties to understand the intention of the last question, aiming to gain information about reasons for choosing a health center. Spontaneously the patients often said that they come because they want to be treated not because water or electricity are available. Still those two things are acknowledged as helpful to be able to take drugs immediately or to visit the health center day and night. The answers for the last question give the impression that the accessibility plays an important role in choosing a health center, but also if the people are friendly and if a good service is given (see Table 5.1 and Figure 5.6). This is also reflected by comments given from patients:

“I come here because this is the HC which is near to me and it gives good services to me.”

[Rusatira, IG70]

More than 150 patients (33 %) mentioned as one of the main reasons to attend this health center, that the Mutuelle de Santé is registered there. In some cases they also said, that they would be transferred to a hospital in Butare if necessary. Especially for patients coming from a neighboring district this seems to be attractive. Also family members living closer to Butare would be more helpful in case of a transfer:

> *"If you are transferred from Karama they go to Butare (CHUB), from health centers in Nyaruguru they are transferred to Munini. Butare is preferred since family is near."*
>
> *[Karama, MJ18]*

Table 5.1: Answers to Question 24: "How true are the following statements regarding your decision for coming to this health center today?" Or "At what level do you agree with these sentences?" (answers with more than 30 % are marked grey)

	Very true of me	True of me	Neutral	Untrue of me	Very untrue of me
a) This is the only health center I know.	38	13	0	182	243
b) This is the nearest health center.	256	149	0	33	37
c) This is the health center with the best access by public transport.	133	108	3	158	74
d) This is the health center which I can access the quickest way.	267	138	0	35	36
e) This is the health center which I can access the most comfortable way.	155	202	4	83	32
f) This is the health center which I can access the most affordable way.	115	135	5	145	76
g) I know about the good service here.	125	252	12	56	31
h) I have been here before.	129	104	6	146	89
i) People are friendly.	155	229	9	53	28
j) It was recommended.	40	14	1	172	246
k) They have electricity.	51	23	3	87	310
l) They have water.	65	29	1	88	291
m) I want to visit family members or friends on the way.	9	8	2	106	351
n) There is a market in this area today.	42	5	2	87	340

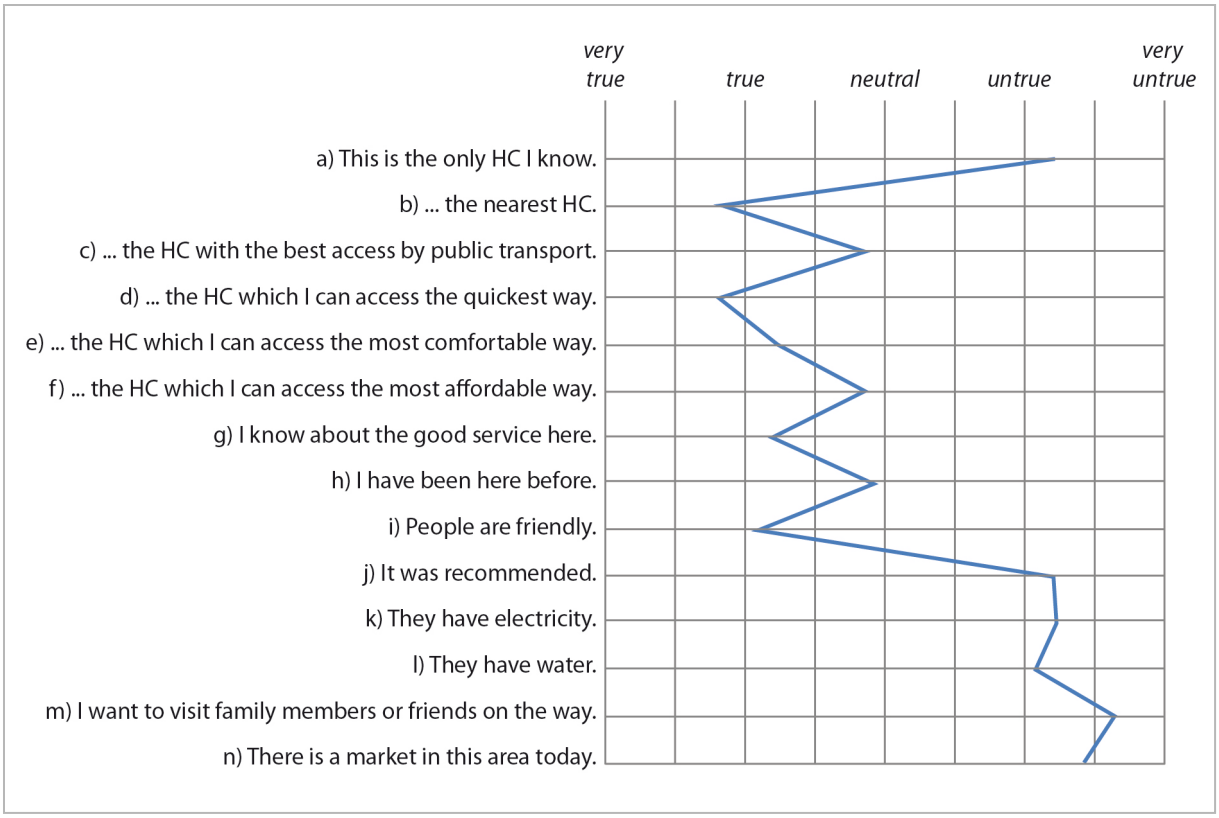

Figure 5.6: Profile line of answers to Question 24

5.1.3 Summary by health center

Although patients at **Busoro-Gishamvu** HC are well covered with health insurance (Mutuelle de Santé) a high number considers going to the pharmacy first, consulting a community health worker or using traditional medicine seeking for medical care. In general the patients' opinion of the health center seems to be poor. Especially with a high number of patients present at the health center, customer care is said to decrease:

> *"It depends on the number of patients present, if they are few, they care/are friendly, if they are many they don't."* *[Busoro-Gishamvu, IG102]*

Also the equipment is experienced as insufficient. The proximity to the health center (or the high distance to other health centers) is obviously one of the main reasons to come here despite the poor public transport. The high utilization rate from the neighboring district Nyaruguru can be explained by (1) the high distance to the next health center in the own district as well as (2) the possibility of being transferred to the hospital in Butare which has a high reputation.

In contrast **CUSP Butare** HC seems to be very popular, which can be explained on the one hand by the good accessibility by public transport but also by a high opinion of patients about the quality. Also good conditions of the building and sanitation are recognized. Still also here patients complain about bad customer care and slow service:

> *"They don't care about the patients; they also have moral corruption – if they don't know you they don't care about you."* *[CUSP Butare, MW61]*

Huye Police HC is one of the four health centers in or close to the city of Butare and is situated at the unpaved national road through the south-west of the district. Here public transport is available and also used by almost 20 % of the patients to reach the health center. Still patients experience problems with the accessibility of trails they are using, especially during the rainy season.

A high number of patients is insured with RAMA (23 %) but also comparable many patients are not insured at all (9 %). In relation to the administrative area of the health center patients travel longer to the Huye Police HC. Still about half of them feel to access the health center the quickest way.

The health center in **Karama** receives also patients from the neighboring district Nyaruguru although at least for some of them the health center there would be nearer. The health center is run by sisters (religious) and patients seem to have a high opinion about it:

> *"Even though it is somehow far from home compared to Kibeho we choose this health center because they provide good medical services."* *[Karama, KB4]*

Karama HC is situated in a very rural area where patients are coming by foot only. During the rainy season they partly have to use different trails to reach the health center. Surprisingly the public transport is seen as good and patients feel positively about accessing this health center the most comfortable way. Also here the option of being transferred to the hospital in Butare favors the utilization of this health center.

Also **Kinyamakara** HC is placed in a very rural area where public transport is recognized as very bad and thus almost 100 % of the patients are coming by foot. Here the share of students, who are coming mainly from the boarding school in the area, was comparable high. While some patients are happy with the way the health staff cares about them, others complain about insufficient drug supply as well as about the bad condition of the building, the lack of electricity and safe water.

Matyazo HC is also run by sisters. Situated at an unpaved national road close to the city of Butare, one third of the patients uses public transport to reach the health center. Patients complain about the insufficient drug supply especially concerning expensive drugs which they have to look for in pharmacies. While some patients acknowledge the quick service and good customer care as well as a good sanitation at the health center, others complain about spending a lot of time waiting for treatment, the bad customer care and getting always negative test results. Although the health centers are open 24 hours every day (SR. ATANASIE, 2011) patients sometimes have to wait long in the evening or even might be sent home without treatment:

> *"They don't care about the patient. If you come here in the evening hours doctors can abandon you telling you that it's too late."* *[Matyazo, MW6]*

Mbazi HC is located in a rather rural area with a comparable high percentage of patients being insured with FARG. Patients here report to have difficulties in accessing the health center by the same trail during the rainy season. They are mentioning a health center (probably a health post) in Tare which seems to be a branch of Mbazi HC. Although this health post is said to be closer to home for some patients they favor Mbazi HC because of the good service they receive here. Data received in 2012 concerning health posts in Huye District does not reveal information about a health post in Tare

Though **Rango** HC is further away from the city center of Butare than Huye Police and Matyazo, it is still situated in the urban area of the district at a paved road (see Figure 5.7). Here the highest number of patients reports the necessity of using a different trail during the rainy season to reach the health center (about 20 % of the patients). Although public transport should be well available in this area, also here about 80 % of the patients come by foot and 35 % of the patients need more than one hour to reach the health center. Also in Rango the share of patients considering seeing first a local health advisor is with 21 % comparable high.

Rubona HC, located at the paved national road coming from Kigali and leading to the city of Butare, is well connected by public transport which is reflected by only half of the patients coming by foot. Patients in Rubona rank the health center among the best health centers.

Figure 5.7:
Paved road passing Rango HC

Ruhashya HC is the only health center where no student was participating in the survey. Placed in a quite rural area, public transport is poor and patients are mainly coming from home by foot to seek for care at the health center. During the rainy season paths are more difficult to access. Still 90 % of the patients report to travel only up to one hour.

At **Rusatira** HC, although situated at the paved national road leading to Butare, utilization of public transport is low (10 %). Patients here most probably come because it is the nearest health center or because the Mutuelle de Santé is registered there, but a quarter of the patients participating in the survey acknowledged the good service and that the health staff cares about the patients. Only a few mentioned a delay of services.

At **Rwaniro** HC the share of parents accompanying their children was the highest, thus also mainly coming from home. Here a higher number of patients are reporting to use traditional medicine for first treatment. Still, they rank their health center among the best health centers they know. People use the health center in Rwaniro because it is the nearest, but also the one they can access the most comfortable and the most affordable way. Furthermore patients perceive to be well treated and cared for at this health center. At the time of the survey Rwaniro was the newest health center in the district, which was newly built in the rural area of Rwaniro sector. People had the impression that it is better equipped than other health centers also concerning sanitation. Still they mentioned the lack of electricity.

Simbi HC is another health center that is situated far from a main road. It receives a high number of farmers who come mainly from home to seek for health care at the health center. Also here patients have problems to use the same trails during the rainy season. At Simbi almost half of the patients reported to have been travelling more than one hour to reach the health center. One third of the participants mentioned to see a community health worker or a local health advisor for receiving first health care.

Some patients at Simbi HC mention the health post in Shanga cell (Maraba sector), which was a branch to Simbi HC at the time of the survey and was transformed into a health center in 2011. Patients do not seem to differentiate between those two in regards of what services are offered. Instead they perceive an option of choice. Thus it can be assumed that a high number of patients in the area of this health post are making use of it. Where both are almost in the same distance the quality of the road seems to have an impact:

"We come here because it's a good road compared to Shanga HC." *[Simbi, KB139]*

Also at **Sovu** HC the share of farmers is very high and only 73 % of the patients interviewed have visited a school. A few patients say to make use of a different trail during the rainy season. More than half of the patients were estimating a distance of only up to 1 km from home to the health center. With 100 % of the patients being covered by Mutuelle de Santé also all of the patients favor the health center for seeking health care. Most of the nurses are sisters and patients acknowledge the good customer care. Though most of the patients are coming by foot they say to come to this health center because they can access it the most comfortable way.

Although the official information is that patients can register for Mutuelle de Santé at any health center (FISCHER, GTZ, 2010), only few of the patients seem to be aware that they have a choice to which health center they can register in Mutuelle de Santé and resulting from this to which health center they would go for seeking care.

5.2 Data collection from registration books

Although all available books have been copied the data does not always match with the numbers given in the HMIS. While for Mbazi HC almost three times as many patients have been registered for the survey in comparison to the official data, for example at Huye Police HC only 17 % of the official number could be registered although all available data was entered in the database (see Figure 5.8). Health centers marked with * have been fully collected, the others partially.

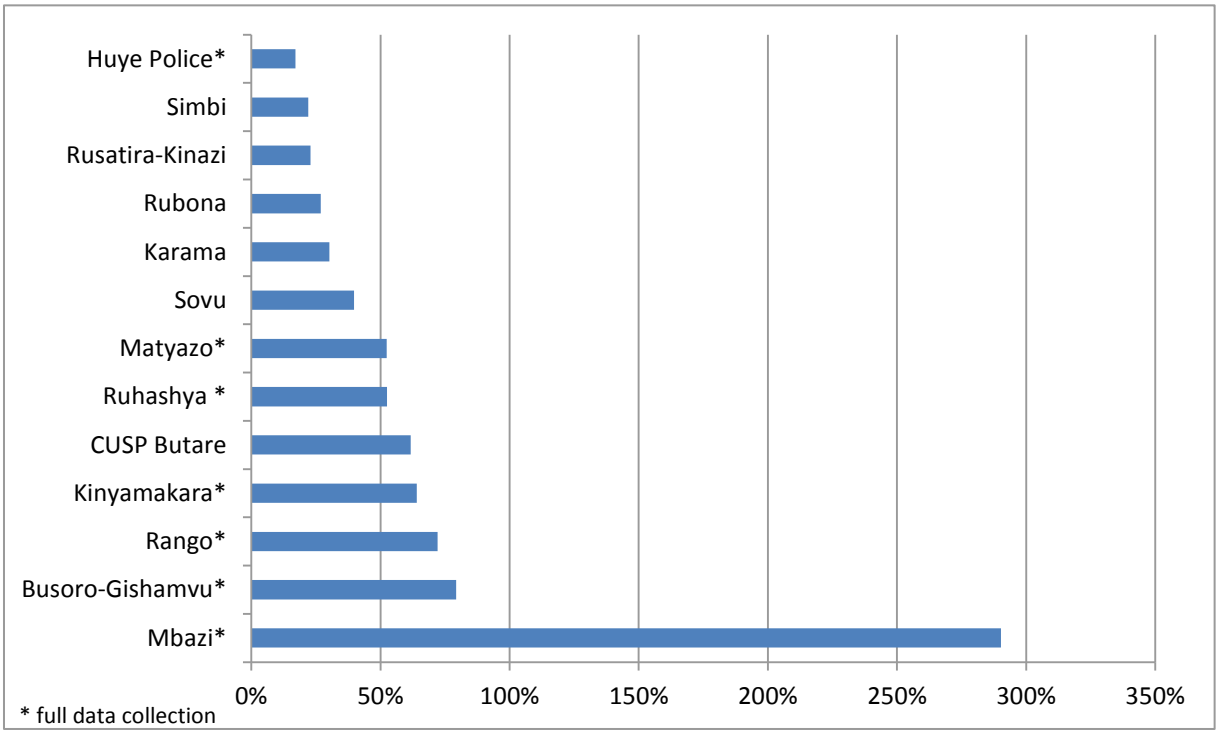

Figure 5.8: Percentage of registered patients in comparison to official numbers (MOH, 2011)

For March 2010 in total 15,645 and for July 2010 10,712 patients have been registered. Comparing the health centers the disparities are high for the difference between the months which can be caused by the different methods of data collection (see Figure 5.9).

For all health centers a higher share of female patients was reported. In total about 60 % of the patients have been female. While this is also for the majority of health centers the case, in Mbazi, Rango and Simbi the number of registered women even doubled the number of men (see Figure 5.10). The census data of 2012 reported a sex ratio of 93 for the Huye District (48.2 % male population), which is also the rate on national level (NISR, 2012a:18).

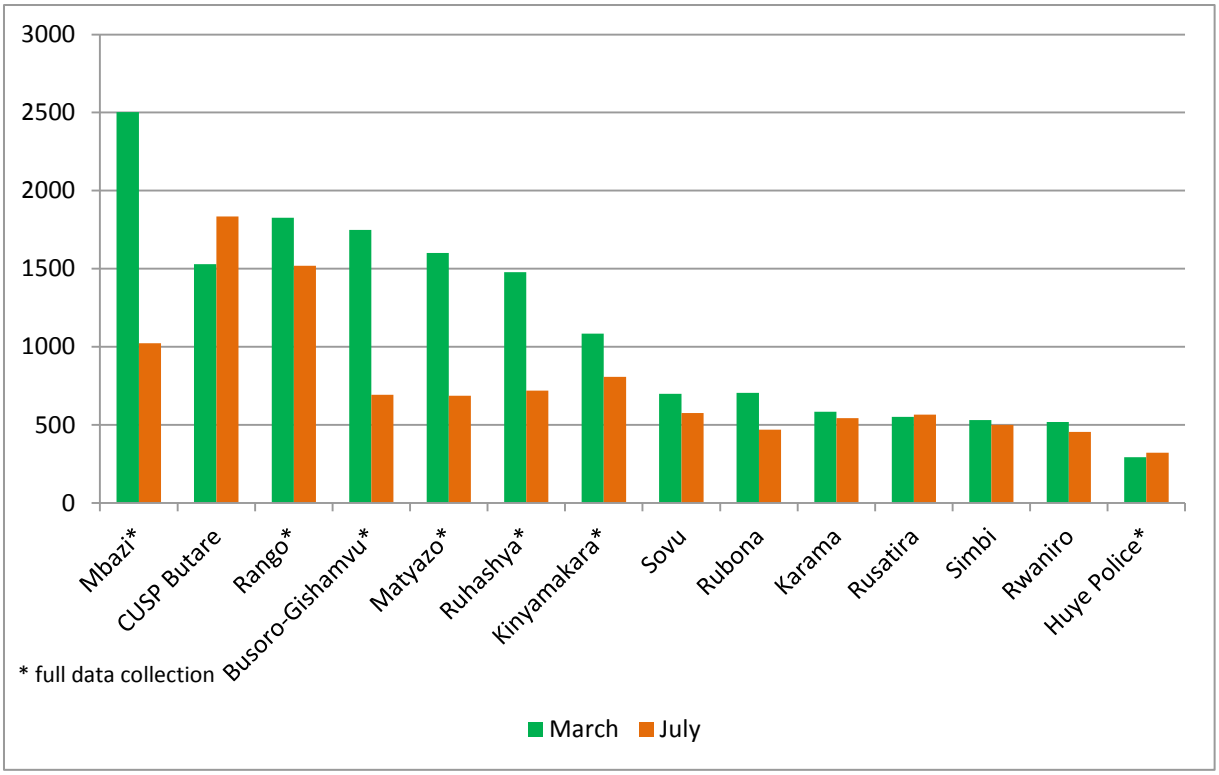

Figure 5.9: Collected data per health center and per month

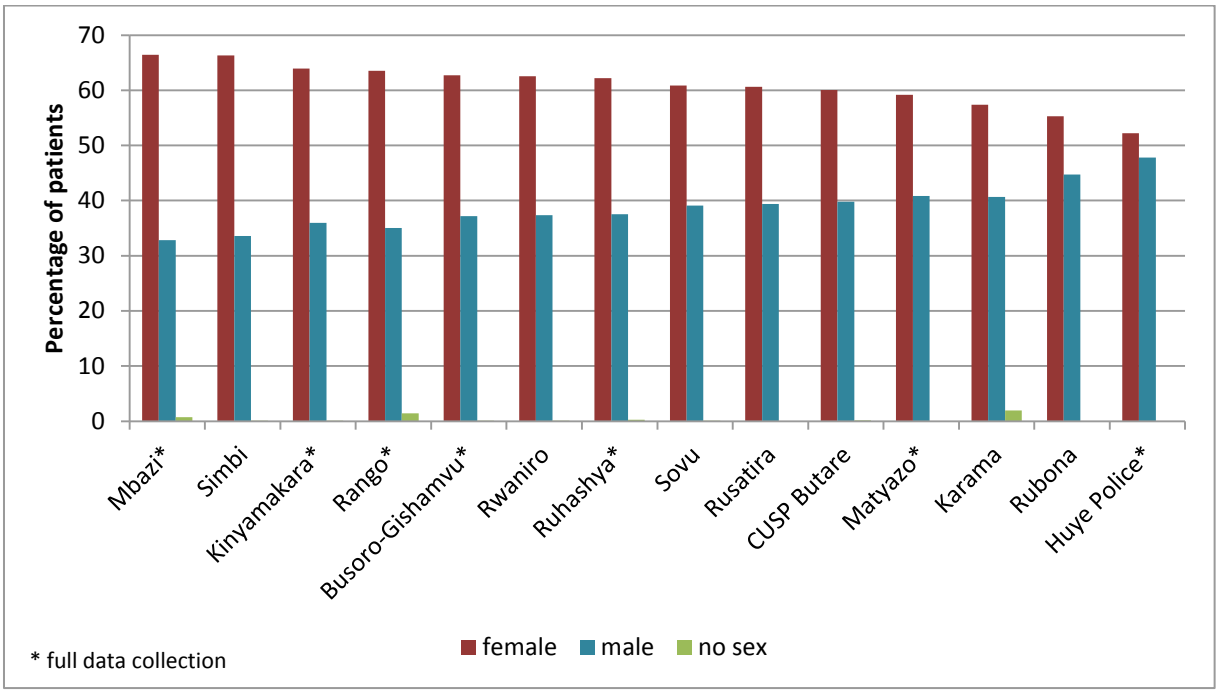

Figure 5.10: Percentage of patients per sex and health center

In interviews with staff at health centers it was already mentioned that in general more patients are coming Mondays (after the weekend) or Fridays (before the weekend). This could be confirmed through the registered data: For most of the health centers a steep

decline in utilization can be observed with a peek on Fridays and low patient numbers on weekends. At the time of the survey patients were charged a higher consultation fee on weekends. For Simbi a high number of patients is remarkable for Thursdays. In 2010 on Thursdays special activities (maternal care) were taking place at Simbi HC. The data collection was also done on a Thursday and a lot of pregnant women were present.

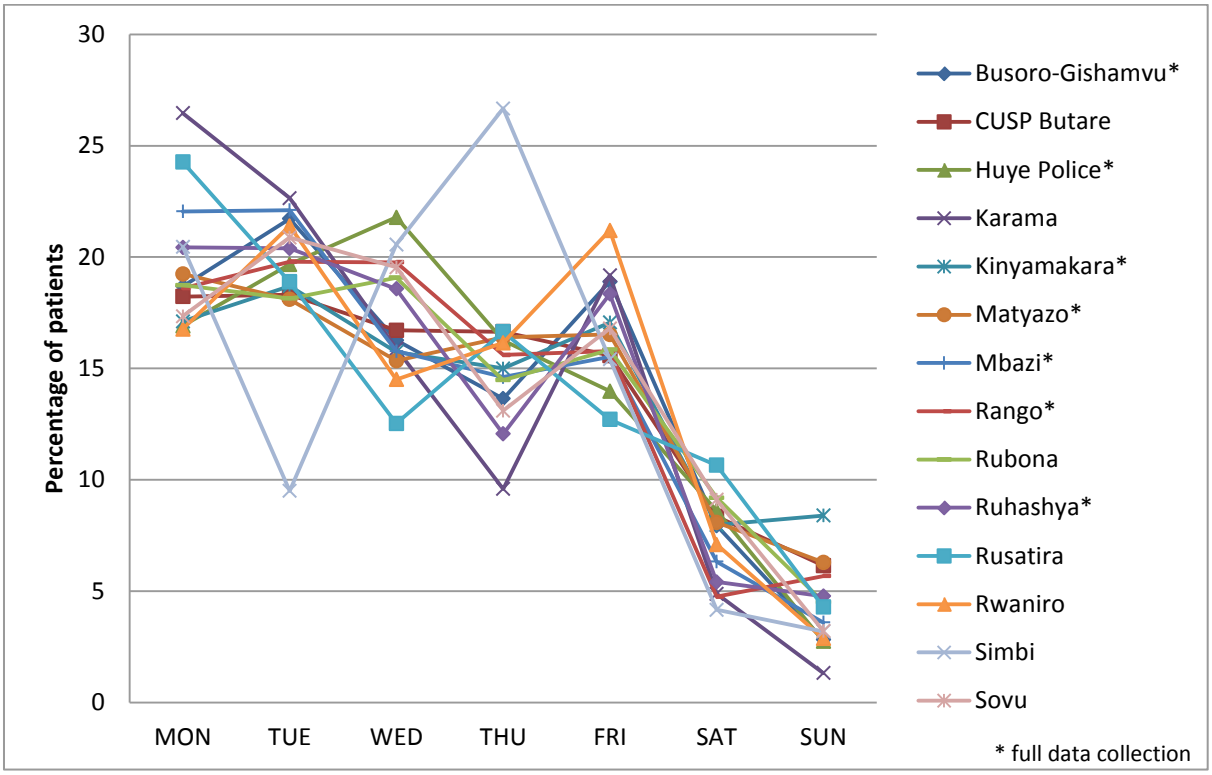

Figure 5.11: Percentage of patients per health center and day of the visit

While for Simbi HC a very low rate of patients below the age of 5 is reported in combination with a very high rate of patients between 25 and 49, for all the other health centers a high number of children under five can be observed but also the age group of patients between 25 and 49 is again highly represented. The low number for Simbi for children younger than 5 years is probably caused by the selection of books recorded. With almost 30 % this age group is in total over represented compared to the national average of about 15, while the oldest age group only covers about 13 % (10.4 % on national level)(NISR & MINECOFIN, 2012b:19). The remaining groups each cover about 20 %. The comparable high number of patients between 15 and 24 at CUSP Butare can be explained by the proximity of secondary schools and the University (former National University of Rwanda) in the area of the city of Butare.

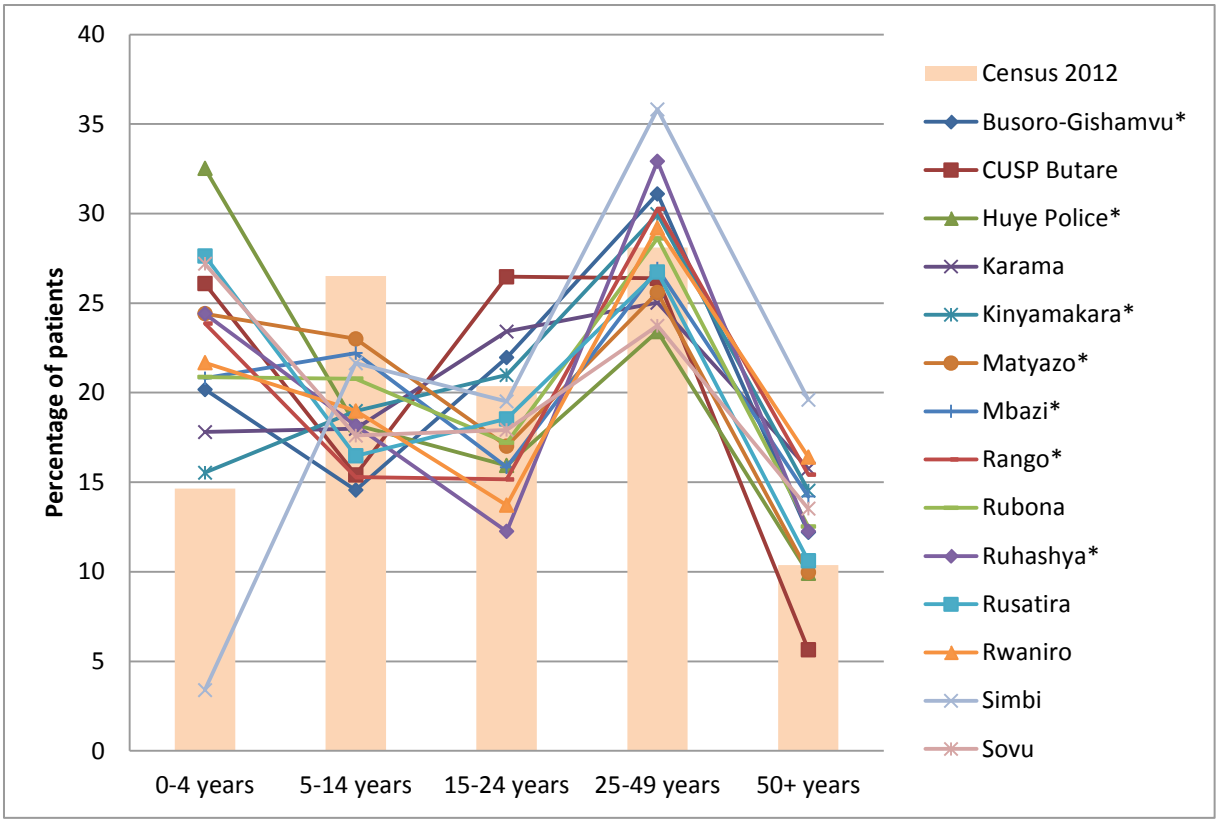

Figure 5.12: Percentage of patients per health center and age group (groups as given in registration books) in comparison to census data (Source for census data: NISR & MINECOFIN, 2012b)

Comparisons to official HMIS data from 2010 show high discrepancies especially in regards of patients coming from a different health center area (HZ, see Table 5.2). While the HMIS reports high numbers of patients coming from a different area for Kinyamakara where for this study the numbers are neglectible, the survey finds more than a third of patients at Matyazo HC coming from another area where in contrast in the HMIS data this number is below 1 %. In general the percentage of patients coming from a different area was higher for this survey than reported. It can be assumed that these differences are caused by recording mistakes because this information used to be recorded manually and by knowledge of the staff at health centers. This might have also led to the change in the last years that this data is not reported anymore.

Table 5.2: Utilization rates in percent at health centers by aggregated residence in comparison to HMIS data for March and July 2010 (MOH, 2011)

	Data collection			HMIS data		
Health Center	Z	HZ	HD	Z	HZ	HD
Busoro-Gishamvu	59.2	2.3	38.5	74.7	3.0	22.4
CUSP Butare	19.7	57.6	22.7	27.5	45.8	26.7
Huye Police	62.1	35.4	2.4	95.2	0.6	4.2
Karama	95.6	0.7	3.6	97.6	2.2	0.2
Kinyamakara	99.5	0.3	0.2	69.1	30.5	0.4
Matyazo	62.9	36.8	0.3	99.0	0.9	0.1
Mbazi	98.6	1.1	0.3	97.7	0.5	1.8
Rango	99.0	0.3	0.7	97.8	1.4	0.9
Rubona	98.4	1.4	0.3	98.1	1.4	0.5
Ruhashya	99.2	0.8	0.0	95.4	3.8	0.9
Rusatira	99.6	0.2	0.2	99.4	0.3	0.3
Rwaniro	99.0	0.9	0.1	-	-	-
Simbi	97.3	1.9	0.8	99.3	0.6	0.1
Sovu	46.5	53.5	0.1	65.6	34.2	0.2
Total	78.5	14.6	6.9	85.0	10.1	4.9

On village level between one and 240 patients have been registered, this is up to almost 50 % of the reported population of 2012 (NISR & MINECOFIN, 2012b; see Figure 5.13). From 14 villages no patients have been registered. It is obvious that utilization rates decrease rapidly with increasing distance from health centers. For all health centers a clear drop of utilization by villages in a road distance of more than 5 km is visible.

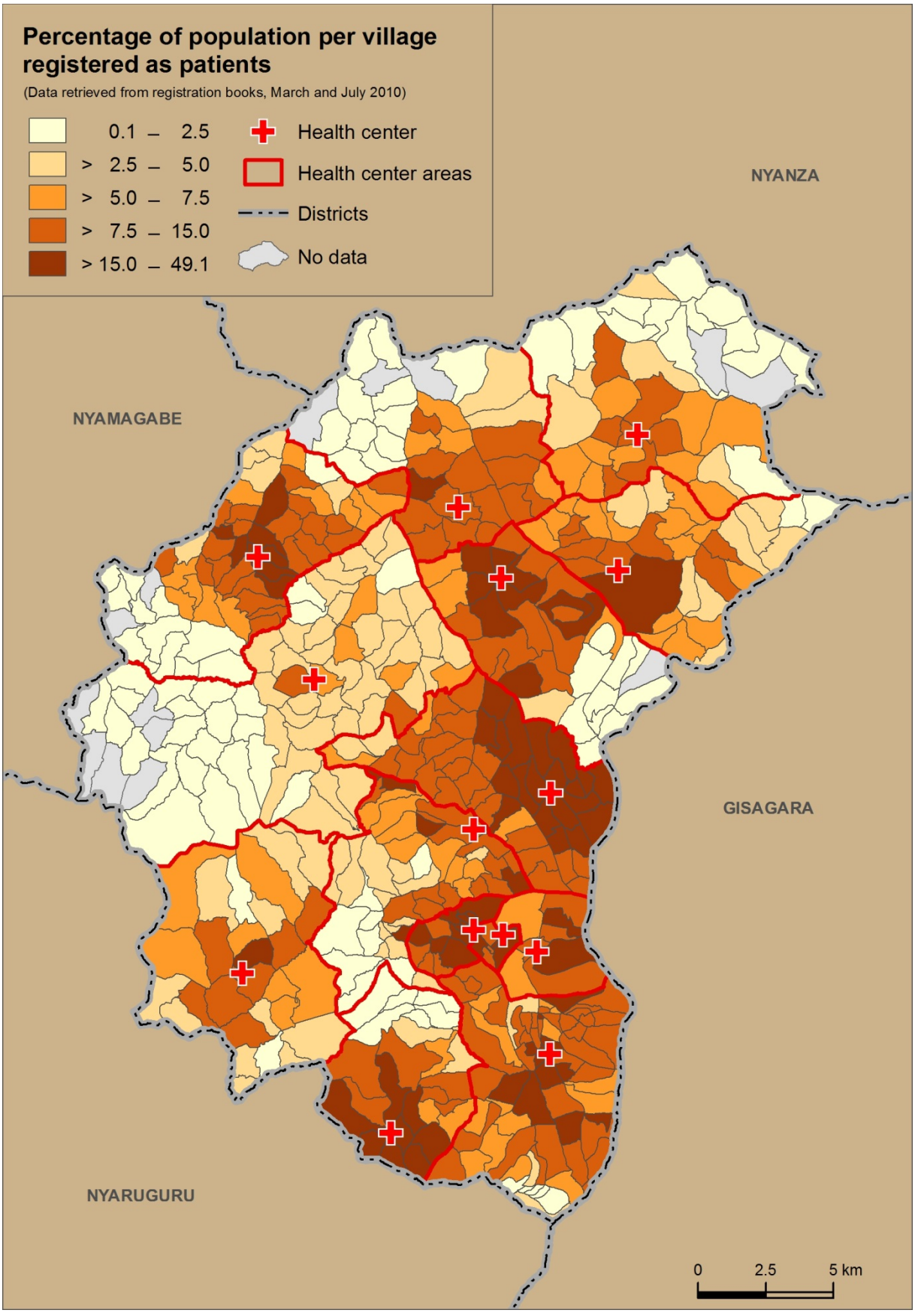

Figure 5.13: Number of patients as percentage of population per village

5.3 Spatial Analysis

5.3.1 Spatial distribution of questionnaire respondents

Most of the patients could be assigned to a village. For only 32 patients this was not possible due to missing (11 patients) or invalid data. The remaining 444 cases patients were assigned to in total 247 villages from which 227 (414 patients) are laying inside the study area of Huye District, 20 could be found in the districts of Nyanza (1 village), Gisagara (12 villages), and Nyaruguru (7 villages) with in total 30 patients (see Figure 5.14).

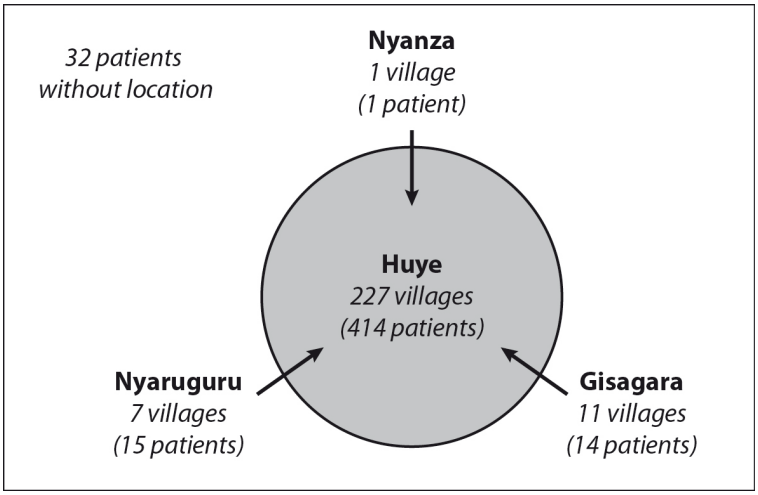

Figure 5.14:
Origin of patients responding to questionnaire

Figure 5.15 shows the distribution of the patients for each health center in comparison to their administratively assigned area. It also shows that from more than half of the villages no patient participated in the survey. Compared to the data taken from registration books (see section 5.2) this represents the low numbers of patients from areas that are further away from health centers. In Busoro-Gishamvu about half of the patients were coming from the neighboring district Nyaruguru. At CUSP 30 % of the patients are observed to be coming from another district. Also at Karama this share amounts to 15 %. In Sovu and Matyazo the highest rates of patients coming from outside the assigned catchment area are found (54 % and 38 % respectively). For Sovu the utilization by patients coming from Mbazi Sector (which corresponds the catchment area of Mbazi HC) equals the utilization from the assigned catchment area, while 30 % of the patients at Matyazo reported to come from the Huye sector, which is assigned to Sovu HC (see Figure 5.15). This could again be confirmed by data from registration books (see section 5.2).

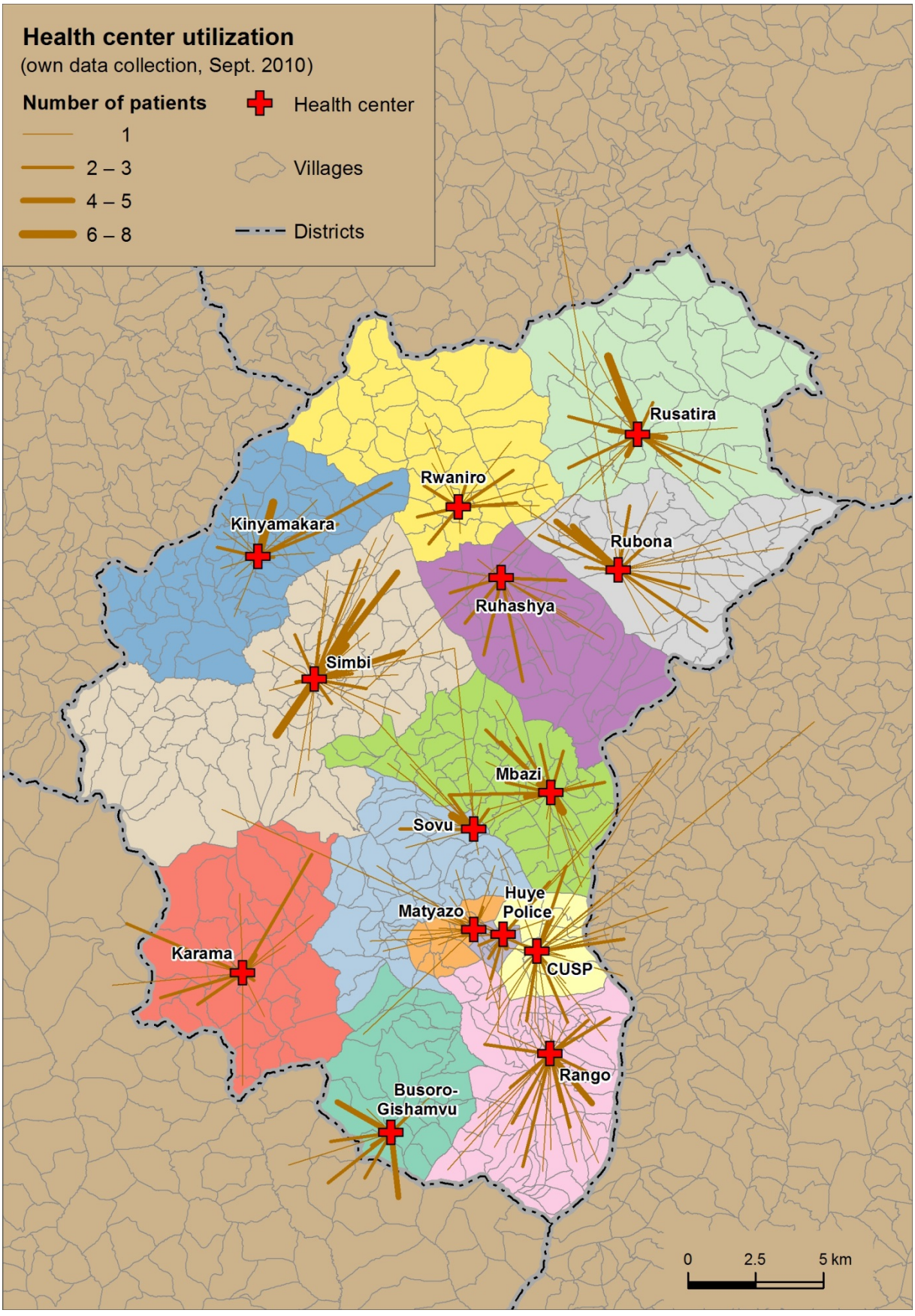

Figure 5.15: Utilization of health centers by village (data collection, Sept. 2010)

5.3.2 Spatial distribution of patients recorded from registration books

Assigning those villages to a health center that more than 50 % of the registered patients are using, Figure 5.16 visualizes the disparities in terms of accordance of the administratively assigned area with the actual utilization. Clearly visible is this accordance for the health centers in Rusatira, Rwaniro, Robuna, Ruhashya, Kinyamakara, Karama and Huye Police. Here the administrative boundary seems to play a major role for the patients in terms of choosing a health center. The map also shows the high utilization of Busoro-Gishamvu HC by the neighboring district Nyaruguru as well as the expansion of the catchment area of CUSP HC to the neighboring district Gisagara. In both cases the next health center in the home district would be further away for most of the patients. In contrast to the above listed health centers, in the central area of the district, utilization differs significantly from administrative expectations (see Figure 5.17). Although in this area the population obviously uses different health centers the catchment areas can be quite clearly distinguished (see also Appendix III). Certainly remarkable is the high expansion of the area that can be allocated to Matyazo HC. This health center seems especially for patients from the Sovu area to be more attractive than their health center. Looking at the boundary between Sovu and Mbazi, for the majority of the patients living in Mbazi Sector, also here seems the administrative boundary in combination with the river to be a reason to go to Mbazi HC. To the north east of Sovu HC a rice plantation that broadens the river might prevent people who are living far closer to Sovu HC than to Mbazi HC on the other side of the river to cross it. Following the plantation further to north west it is replaced by plantations that are mainly rain fed and which are smaller and seem easier to cross. Please refer to Appendix III for detailed maps of utilization for each health center.

The catchment areas are simplified as shown in Figure 5.18 for further analysis. Villages have been reallocated to a different health center where only one or two patients less than the maximum were registered or where the village was building an exclave.

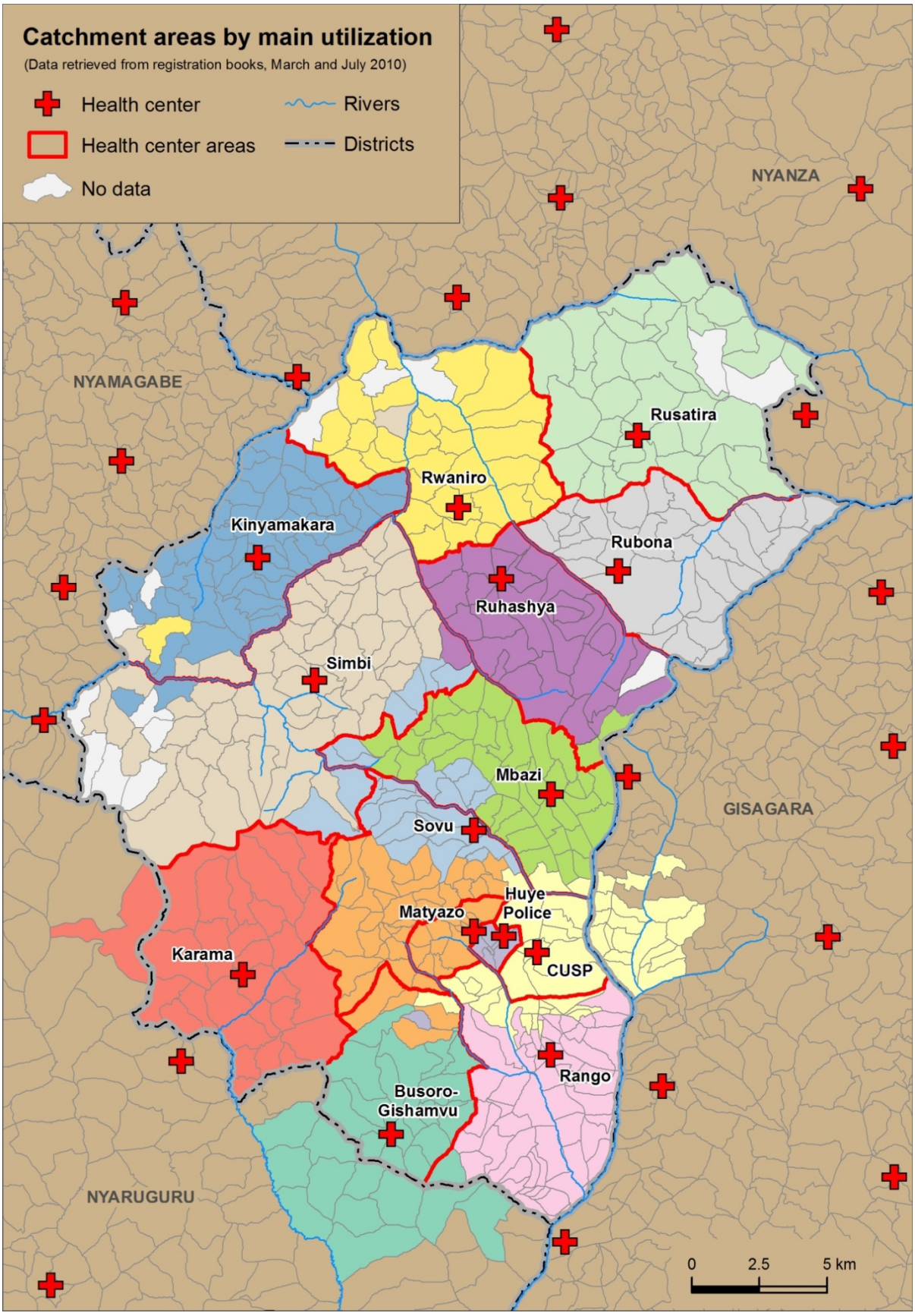

Figure 5.16: Catchment areas for health centers defined by the main utilization from villages

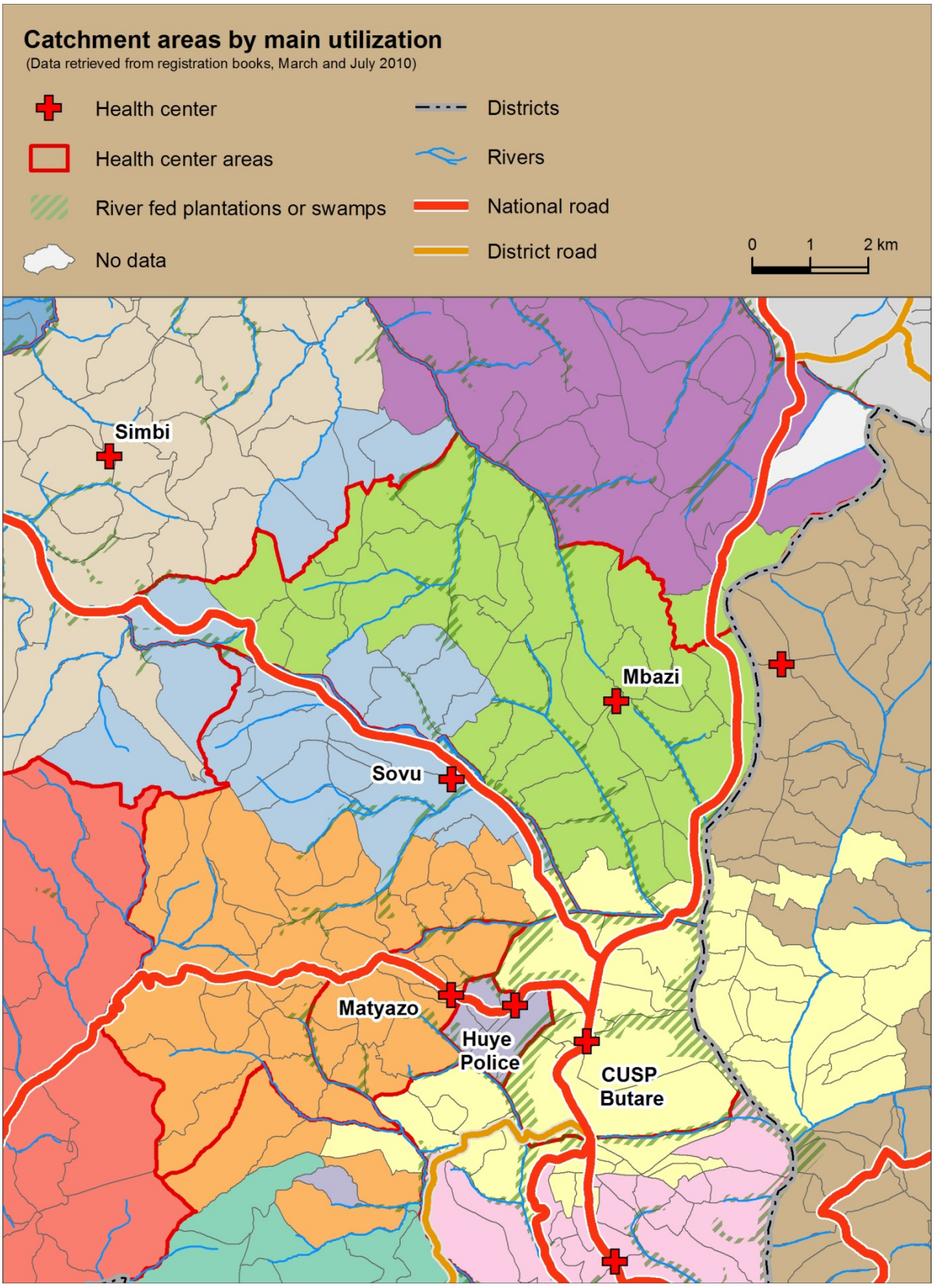

Figure 5.17: Detailed look at catchment areas for health centers defined by the main utilization by villages

Figure 5.18: Simplified catchment areas for health centers based on maximum utilization numbers per village

Looking at differences between the sexes in utilization of health centers small disparities in catchment areas can be determined. For Huye District and the surrounding area in total in about 80 villages female patients use a different health center than male patients. Utilization by month also reveals only a small difference in catchment areas. Again for about 80 villages for March and July different mainly used health centers are reported. The biggest differences can be observed for the areas of Simbi and Sovu HC (see Figure 5.19 and Figure 5.20). While the rivers are easily blamed for the smaller catchment area for Simbi and Sovu HC during the rainy season (March), looking more into the detail in the region of Mbazi and Sovu the smaller streams seem to influence more the catchment area in the dry season (July). At both health centers patients reported difficulties with accessing the health center during the rainy season. How the road access is influenced by the weather conditions needs further investigation (see MURAWSKI & CHURCH, 2009). Except of the national roads bordering Mbazi sector in the east and south, all roads within the sector are unpaved roads.

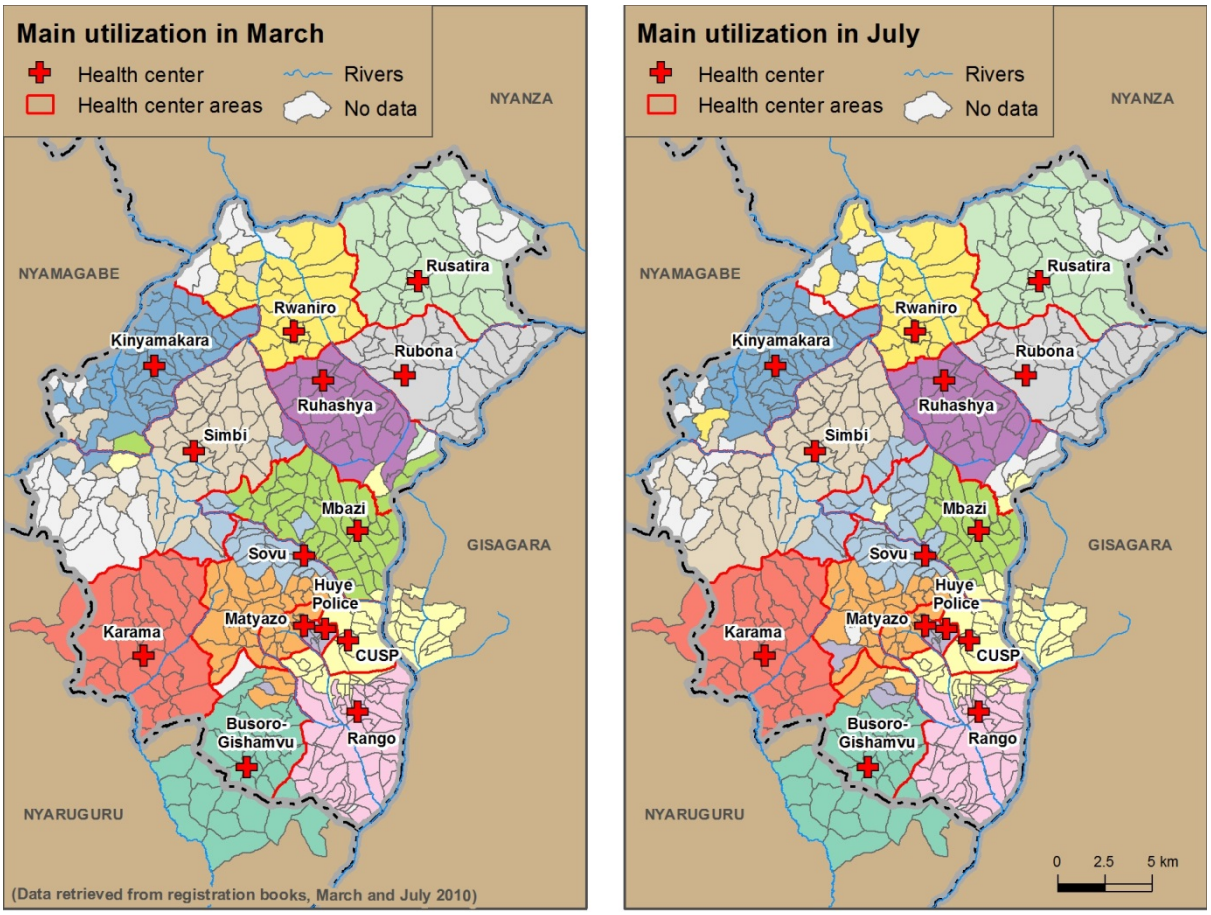

Figure 5.19: Catchment areas for health centers defined by the main utilization from villages by month

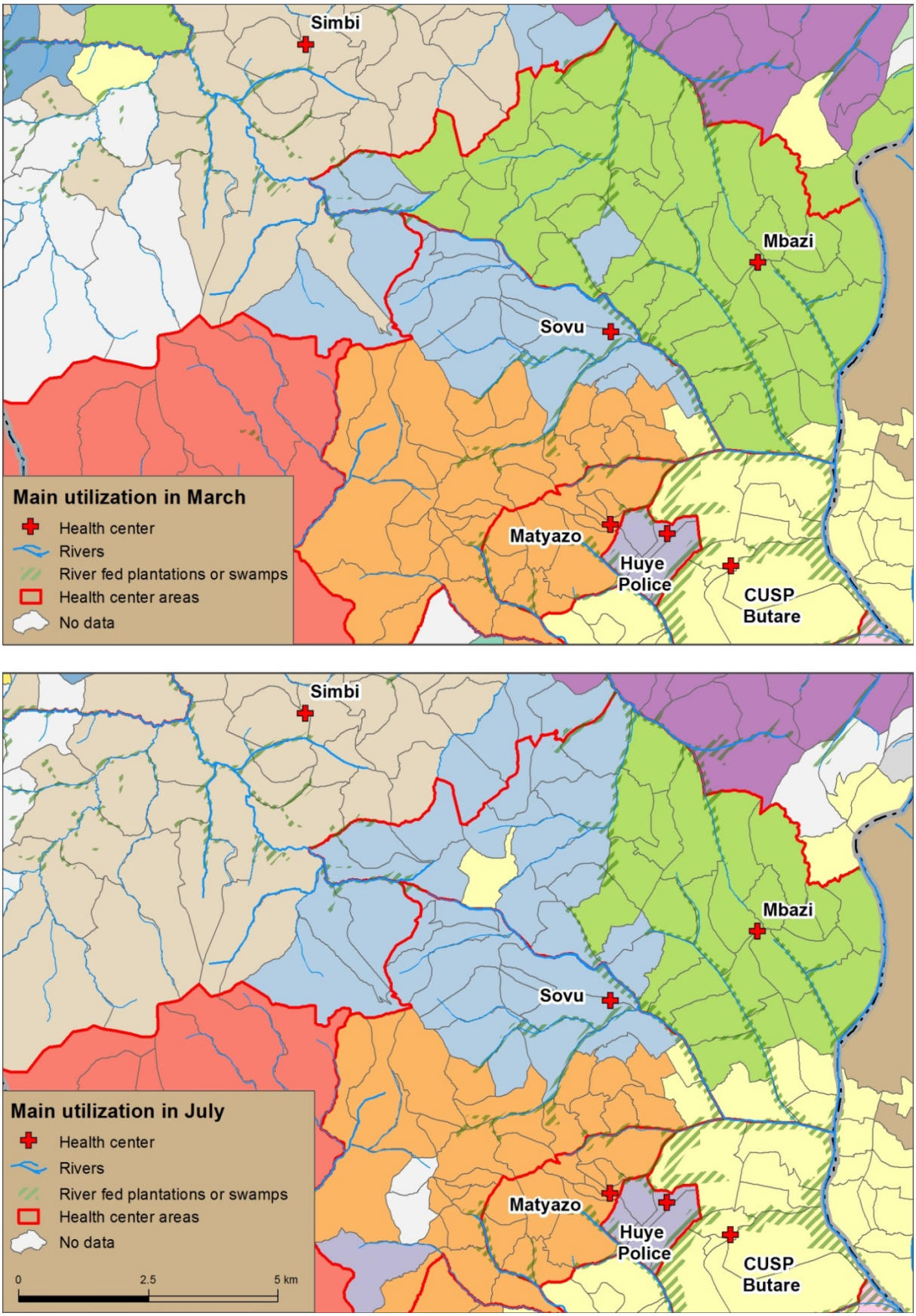

Figure 5.20: Detail view of catchment areas for health centers defined by the main utilization from villages by month

5.3.3 Spatial disparities in health center utilization

Spatial analysis of the data from registration books confirms for half of the health centers the impression gained from the survey that the majority of the patients respect the administrative boundaries of catchment areas assigned to health centers instead of approaching the nearest health center.

While for the Huye District 84 % of registered patients use the administratively assigned health center, Figure 5.21 shows clearly high disparities in the utilization. In the border area between Simbi and Sovu or Mbazi, respectively, as well as for the southern area of Kinyamakara sector the percentage of those patients who do not attend the health center that is administratively assigned to their home village is high. About one fourth of the villages is registered with at least 25 % of the patients using another health center than the administratively assigned one. But it has to be kept in mind that for about 23 % of these villages less than ten patients have been registered for March and July 2010. This concerns mainly those villages with higher rates from Rwaniro, Kinyamakara, Ruhashya and in Sovu those bordering Karama Sector (compare to Figure 5.13). Still, even more severe is the situation in the Sovu area bordering the official catchment area of Matyazo HC where the percentage of those patients visiting the health center in their sector declines down to zero percent and the majority of the patients are visiting Matyazo HC. As well in the latter case as in the case of the border area between Simbi and Sovu/Mbazi the proximity to the health center seems to play only a minor role since the majority is using not the closest health center (see also Figure 5.22 and Figure 5.26). In the most southern village of the Ruhashya HC area the passing national road can be seen as a reason for some of the patients to travel all the way to CUSP Butare HC. Still, the majority is in fact using Mbazi HC which is the closest. In the region where Rango HC is bordering the area of CUSP Butare HC the proximity to the health center in Butare town which has a high reputation most probably causes a high rate of patients not attending their administratively assigned health center.

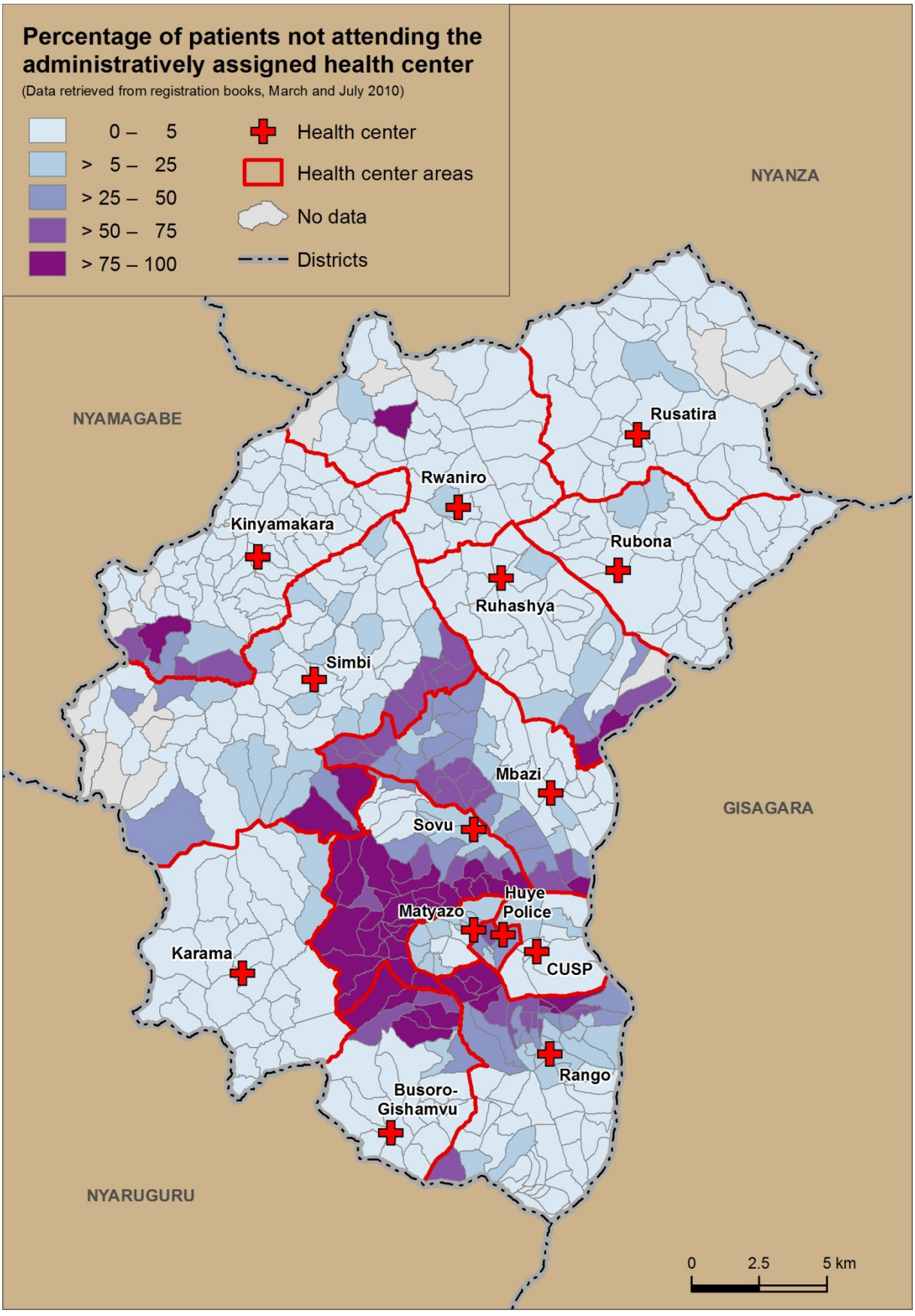

Figure 5.21: Percentage of registered patients per village that are not attending the administratively assigned health center

In terms of availability or spatial accessibility of health center utilization it does not seem to make a big difference if Euclidean or road network distances are taken into account. For almost 80 % of the registered patients the actually used health center is as well the nearest but also the closest health center, taking only health centers in Huye District into account (see Figure 5.22, maps on the left). In this context the term “near” considers Euclidean travel distances while the term “close” is used regarding road network travel distances. For about 10 % of the villages the closest health center is a different one than the nearest. Considering the option to visit also health centers in the neighboring districts, about 17 % of the villages would be nearer to another health center than the administratively assigned one (see Figure 5.22, maps on the right). The share of these villages is slightly smaller when road network distances are taken into account.

For about 5 % of the villages Euclidean distances are almost the same travelling to two different health centers. Between Matyazo and Huye Police HC is for example a village that shows almost equal usage of both health centers, with a slightly higher utilization of Matyazo HC although the village is in the area of Huye Police. The same applies to a village at the border between CUSP Butare and Rango HC: Here both distances are shorter towards CUSP Butare HC which is also slightly higher visited than the administratively assigned health center in Rango (55/43 %), with the remaining 2 % attending Huye Police HC. For four villages in the Simbi HC area the distance to another health center would be almost the same but from these villages all patients attend Simbi HC. In the border area between Mbazi and Sovu HC where the distance to both health centers is almost the same, two thirds of the patients see Mbazi HC but from the remaining share the majority visits CUSP Butare HC although it is further away.

Also in this regards, for the majority of the health centers the administrative boundary of the health center area seems to influence the patients choice more than the distance or proximity to the nearest or closest health center. Of all registered patients coming from the Huye District area 1626 (6.6 %) choose to visit neither the administratively assigned nor the nearest health center nor the closest. From these patients more than 60 % decide to visit CUSP Butare HC instead, 23 % chose Sovu or Matyazo HC.

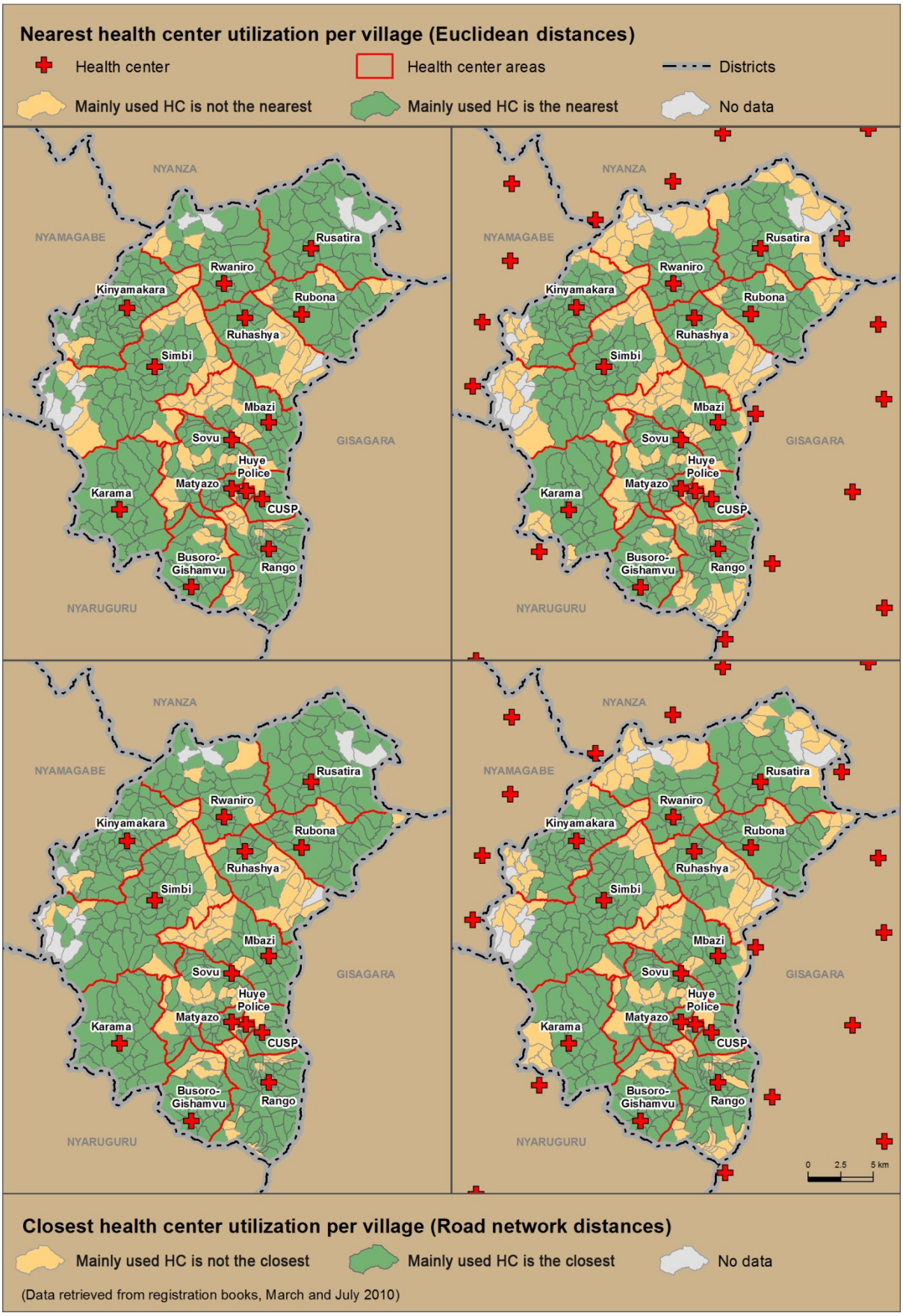

Figure 5.22: Utilization of the nearest (Euclidean distances) and of the closest (road distances) health center per village. Maps on the left take only health centers in Huye District into account, maps on the right also health centers in neighboring districts.

A big share of patients (85 %, n=443) was assuming to visit the nearest health center which could be confirmed for 316 cases (84 %) considering Euclidean distances. The map shows that patients who live closer to the health center are more often correct in assuming that it is the nearest (see Figure 5.23). For 28 patients a health center in one of the neighboring districts would have been nearer. For those patients who marked “untrue” or “very untrue” it is not clear if the proximity does not play a role in choosing the health center or if they think it is not the nearest. For about 10 % of them the visited health center was indeed not the nearest.

From 19 villages patients who answered this question with true or very true were visiting different health centers. In this case one of the patients per village was right, the other(s) wrong. In the map those villages are marked as correct where the number of patients who were right in their assumption was higher than those who have been wrong. If the numbers were equal it was still marked as correct. Only where the number of patients who have been wrong was higher the village was marked as incorrect.

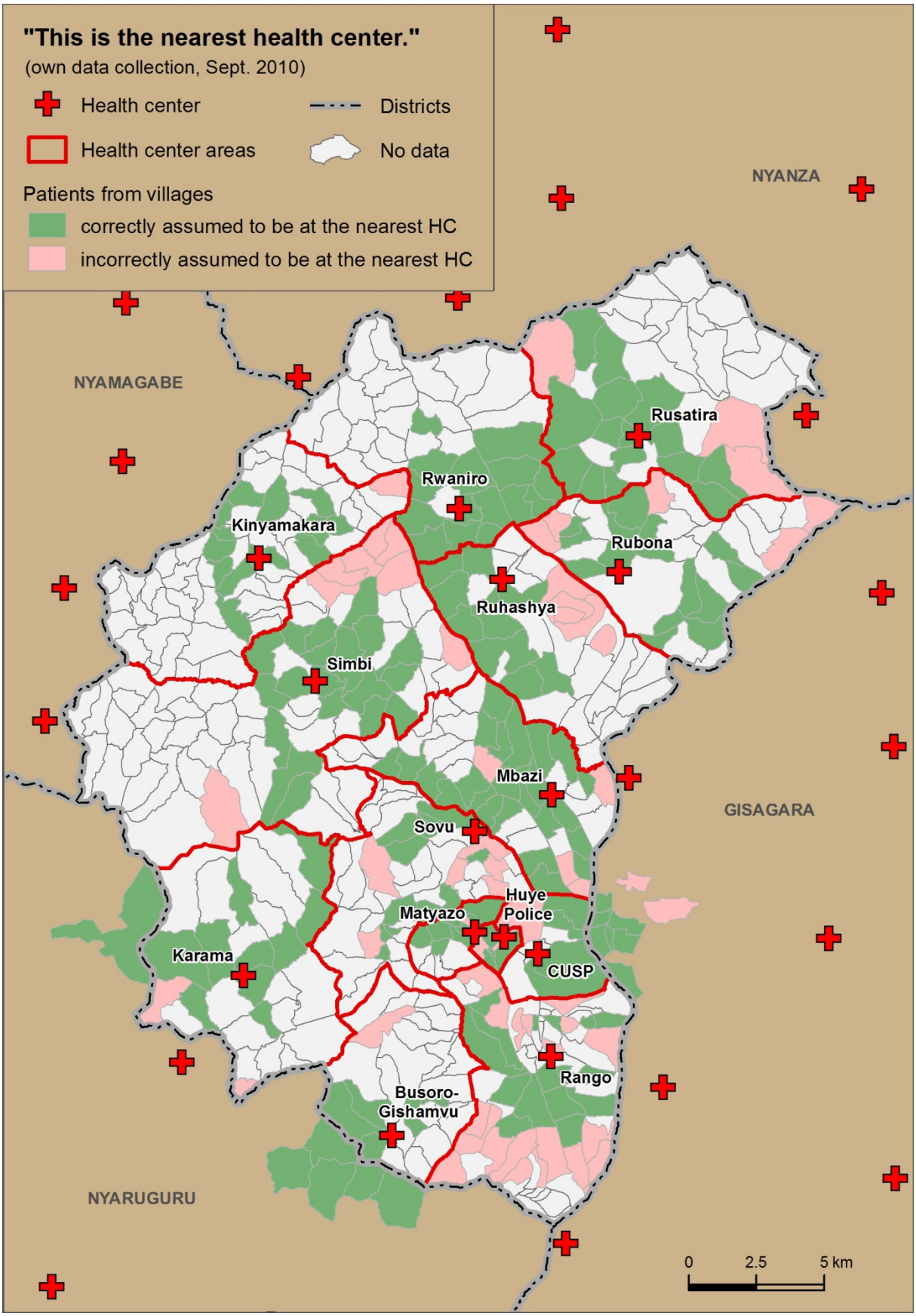

Figure 5.23: Statement 24b of the questionnaire concerning the proximity of the patients' homes to the attended health center

5.4 Modelling catchment areas

5.4.1 Dasymetric population density map

The dasymetric population distribution map (see Figure 5.24) shows the population per square kilometer. In contrast to ordinary population density maps, here most probably unpopulated areas like dense forests, swamps, rivers, mountainous areas, or larger areas with obviously no housing were marked as unpopulated, and the population registered for the village areas by the census of 2012 (NISR, 2012b) were reallocated to the remaining area of the villages (see section 4.2.8 for details). The method could be refined by digitizing unpopulated areas more detailed at a large scale. The calculations are based on raster cells with a resolution of 30 x 30 m and thus give better results for the following population estimates for catchment areas than administrative areas.

While the urban area of Butare shows mainly a high population with more than 900 inhabitants per square kilometer, the majority of the villages in the rural area of Huye District still reports population densities of more than 475 inhabitants per square kilometer which equates to the national population density which ranks belong the top 20 countries in the world (THE WORLD BANK, 2015). The highest densities in Huye District are reported for small villages that show a very high housing density and report more than 300 inhabitants for areas that are mainly smaller than 0.1 km². Still, about 40 % of the district area show population densities of between 130 and 475 inhabitants per square kilometer, only the village of Rubona reports a density of 51 inhabitants per square kilometer only.

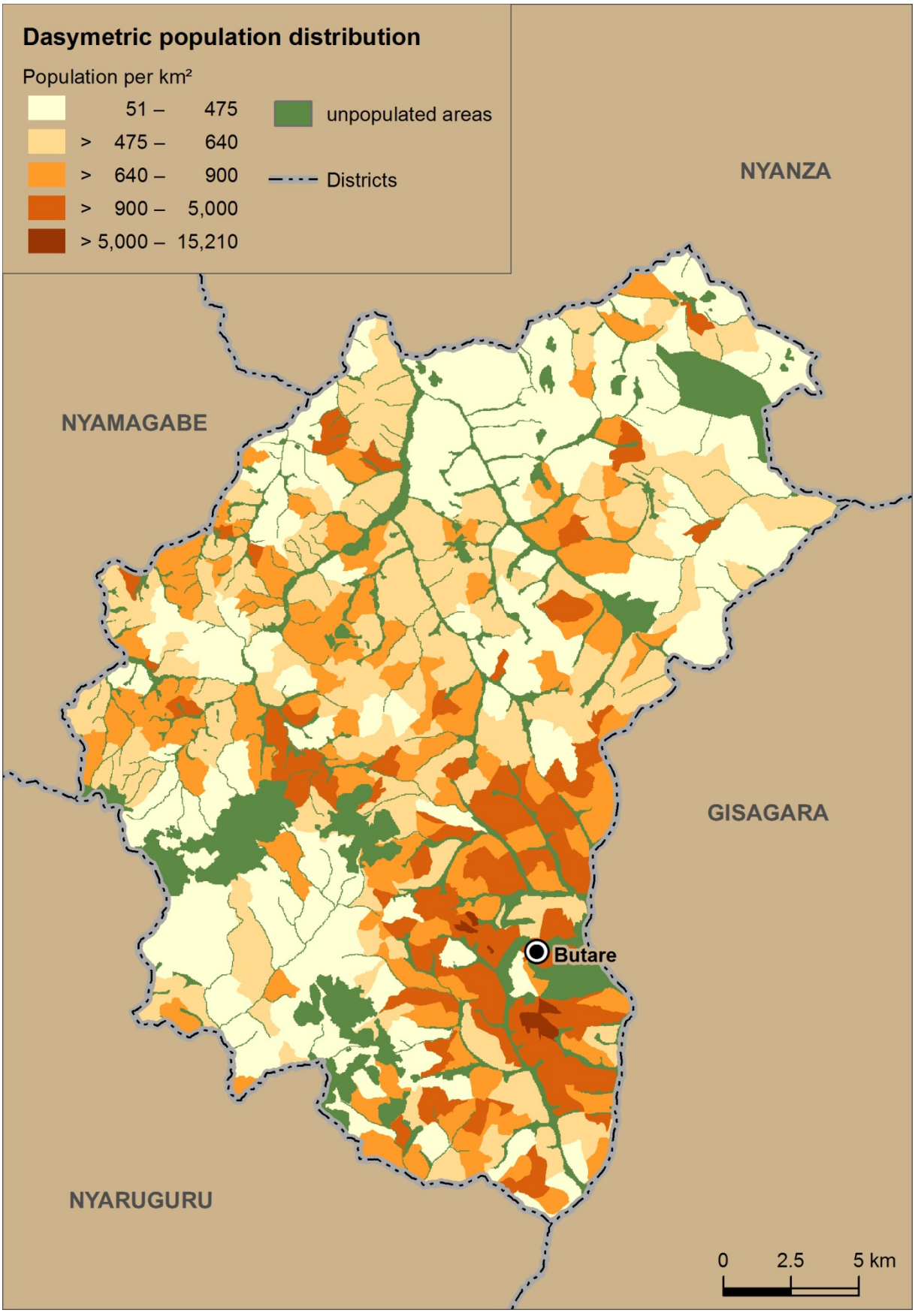

Figure 5.24: Dasymetric population distribution for Huye District

5.4.2 Euclidean distances

Using Thiessen polygons assumes that all patients use the nearest health center and that they use a straight path to reach it (NOOR et al., 2003). Still, Thiessen polygons give a first impression of catchment areas especially for comparing their sizes and can serve as a starting point for further analysis (NOOR et al., 2003; TANSER et al., 2001; ZWARENSTEIN et al., 1991). This is for the African context interesting where spatial data is often missing but can also be used as alternative to the often used method of aggregating administrative boundaries (ALBERT et al., 2000).

For the study area Euclidean distances do not estimate well the served population per health center – compared to the data calculated on basis of the administrative boundaries, as already shown by NOOR and colleagues (2006). While for example on basis of Thiessen polygons the population for CUSP Butare and Ruhashya is highly underestimated (by about 30 %) the population for Matyazo is by far overestimated. This is obviously due to the high distance to the next health center to the west, capturing half of the official catchment area of Sovu HC. The estimates match only slightly better with those calculated from actual catchment areas as defined by data collection results (see Figure 5.25; compare Figure 5.18 and Table 5.3).

Similar to Thiessen polygons, the interpolation of Euclidean distances from villages to health centers make areas with high distances to the next health center visible, showing distances of up to 8.8 km to the next health center in the district. Taking the neighboring district Nyamagabe into account the distance to the next health center is significantly reduced for those villages. Nevertheless nine villages remain with a distance of more than 5 km to the nearest available health center. Population calculations considering the calculated distance to the nearest health center as well as the interpolation of these values (IDW) show that about 90 % of the district population lives within a straight line distance of 5 km to the next health center, taking only health centers in Huye District into account (see Figure 5.25**,** and Table 5.8).

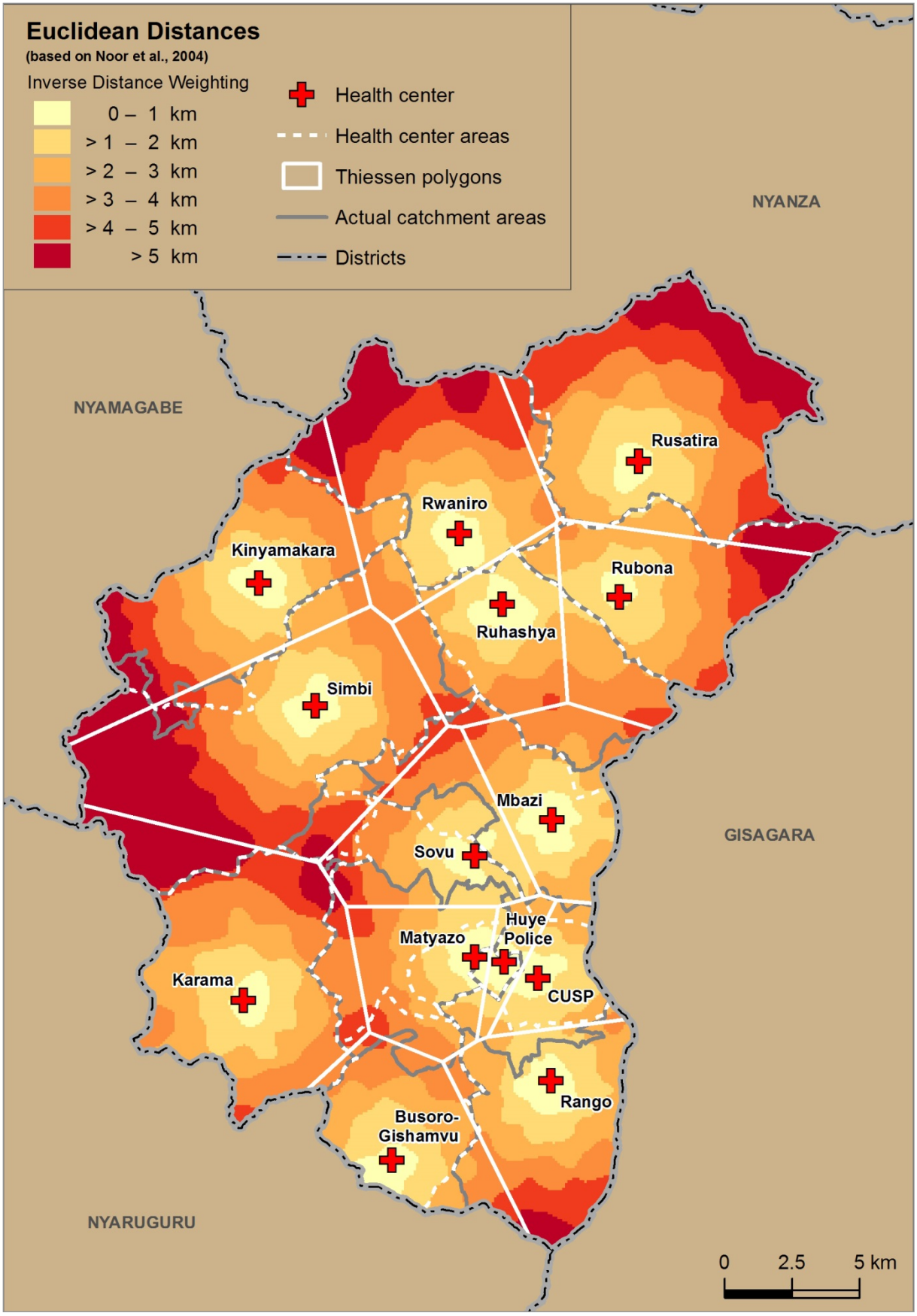

Figure 5.25: Euclidean distances based on NOOR et al. (2004)

Comparing the catchment areas resulting from the nearest health center analysis to administrative boundaries of health center areas, the boundaries between Rusatira and Rwaniro/Rubona, between Ruhashya and Rwaniro, between CUSP Butare and Huye Police, the northern border line of Karama as well as the southern border of CUSP Butare are matching well, while the modelled catchment area of Matyazo represents better the actual utilization. (see Figure 5.26**,** and Table 5.3).

Thiessen polygons give slightly better results than the nearest health center analysis compared to administratively assigned areas; compared to the actual utilization the results are in the average even better and speak again in favor of Thiessen polygons. The nearest method has the disadvantage of requiring administrative boundaries (in this case village areas) that can be aggregated. If village points are available it is possible to use calculated Euclidean distances for modelling a "map of physical access" that covers the whole study area as it was done in Figure 5.25 (NOOR et al., 2004).

Table 5.3: Population estimates per health center for methods based on Euclidean distances

Health center	Admin.	Catchment areas (reg. books)	Method					
			Thiessen polygons			Nearest facility		
			Population	% Admin.	% Reg. Books	Population	% Admin.	% Reg. Books
Busoro	14139	11496	13703	97	119	14501	103	126
CUSP	5222	20265	7330	140	36	6453	124	32
Huye Police	3963	3963	6250	158	158	8369	211	211
Karama	16448	16447	18956	115	115	19336	118	118
Kinyamakara	24473	23763	27607	113	116	29385	120	124
Matyazo	8296	25212	21598	260	86	19846	239	79
Mbazi	30465	27462	21609	71	79	20625	68	75
Rango	46067	32803	39437	86	120	38853	84	118
Rubona	18448	18448	20636	112	112	21769	118	118
Ruhashya	22061	19976	13826	63	69	13612	62	68
Rusatira	26516	26515	30653	116	116	29507	111	111
Rwaniro	23241	23241	23565	101	101	22630	97	97
Simbi	47449	44890	41340	87	92	41253	87	92
Sovu	20770	13070	21040	101	161	21419	103	164
Total	**307558**	**307558**	**307550**	**116**	**106**	**307558**	**117**	**110**

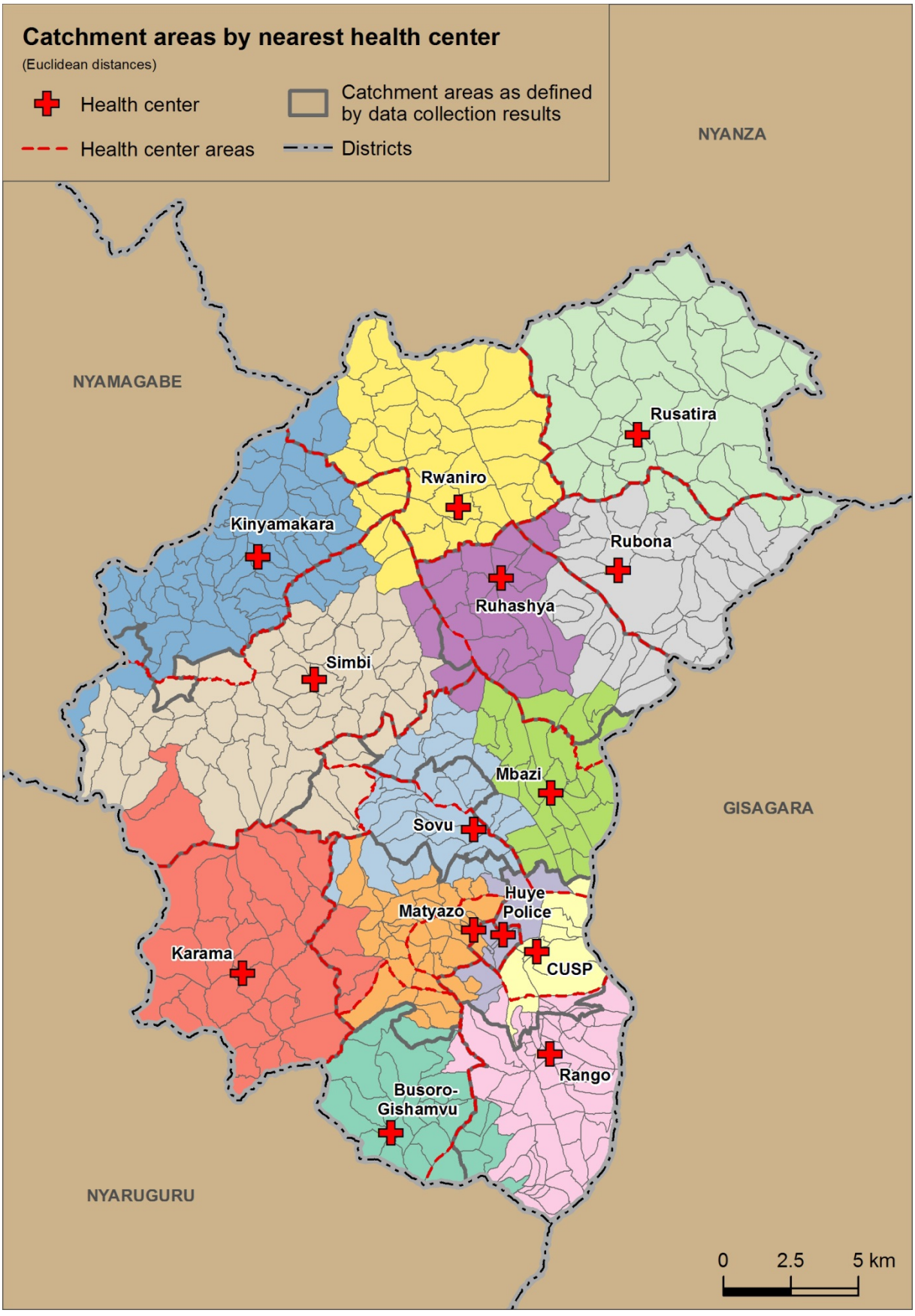

Figure 5.26: Catchment areas by nearest health center based on Euclidean distances between Village centroids and health centers

5.4.3 Cost layer based approaches

Cost distance allocation analysis combine data about rivers, roads, and land cover to calculate the "effort" needed to reach a facility, in this case health centers. The resulting cost distance raster gives an estimation of travel time which was calculated in seconds to represent this effort (see Figure 5.27). While about 54 % of the district population is estimated to reach the health center within one hour travel time, still almost 10 % of the district area is in a travel distance of more than two hours to the next health center. Those areas with the highest values could be covered better by health centers in Nyamagabe District and also in the north of Huye District travel times could be most probably improved by including the surrounding districts. Nevertheless in the south west of Huye District remains an area that is estimated to need up to three hours to reach the next health center.

Allocation areas define catchment areas from where the population can reach the assigned health center with the lowest effort. The map (Figure 5.27) shows that the boundaries of these areas match only for small segments the boundaries of catchment areas as defined by data collection results. The highest conformity is reached in the border area between Kinyamakara and Simbi and for a part of the border between Ruhashya and Rubona. While the allocation area for Huye Police is significantly enlarged towards the south, the area assigned to Ruhashya HC is diminished by this method, allocating big parts of it to Rubona and Mbazi HC. Also Sovu HC receives a larger area through this method, taking parts of the areas that are assigned to Mbazi and Matyazo HC by data collection results. Compared to administratively assigned areas, the population to be served by Huye Police and Matyazo is increased by about 180 % or 100 % respectively (see Table 5.9).

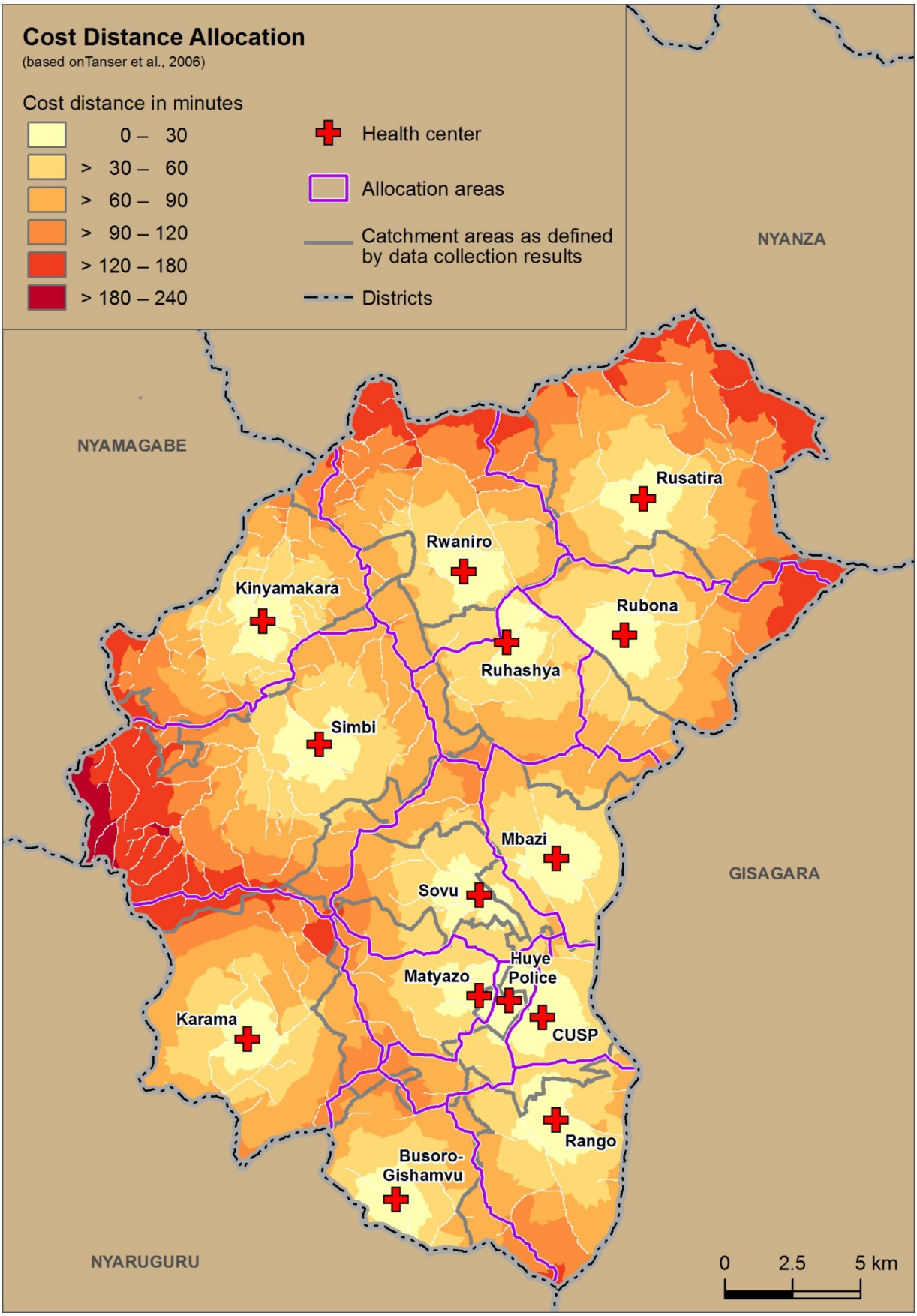

Figure 5.27: Results of the Cost Distance Allocation Analysis based on the method of TANSER et al. (2006:691)

The AccessMod extension for ArcGIS 9.3 works similar to the before described cost distance allocation analysis but includes additionally the digital elevation model and allows to apply different travel speeds for different types of land cover. The results of calculations with the AccessMod extension show only small differences between the two travel scenarios (with and without rivers). Differences of up to 69 minutes of travel time can be found close to the rivers. For both scenarios the maximum travel time within the district is calculated with about four hours. The area that is covered within one hour travel time as aimed by the Rwandan Ministry of Health amounts only 50 % of the district area but about 60 % of the population, taking rivers into account. Also without rivers the results regards covered area and population are only slightly better: almost 51 % of the district area lays within a walking distance of 60 minutes to the next health center which corresponds to 61 % of the population (see Figure 5.28, and Table 5.8).

Similar to the method based on TANSER and colleagues (2006) AccessMod defines rivers as impassable which results in higher travel time values for areas that are surrounded by rivers or streams. With this method the estimates are even slightly higher than with the cost distance allocation analysis based on TANSER and colleagues (2006) and the area of the district from where patients have to travel more than three hours to the next health center is bigger.

The consideration of detailed information about the actual sizes of the rivers and their real impact on traveling times would certainly lead to more correct results for both methods. Until now rivers could only be included as a general factor, while the computed results indicate significant differences in the impact of different streams. This effect increases in areas where rivers have been used to establish administrative boundaries of sectors. On the basis of the current data, however, it is not possible to clarify whether the river itself or the administrative boundary constitutes the predominant factor at a particular location.

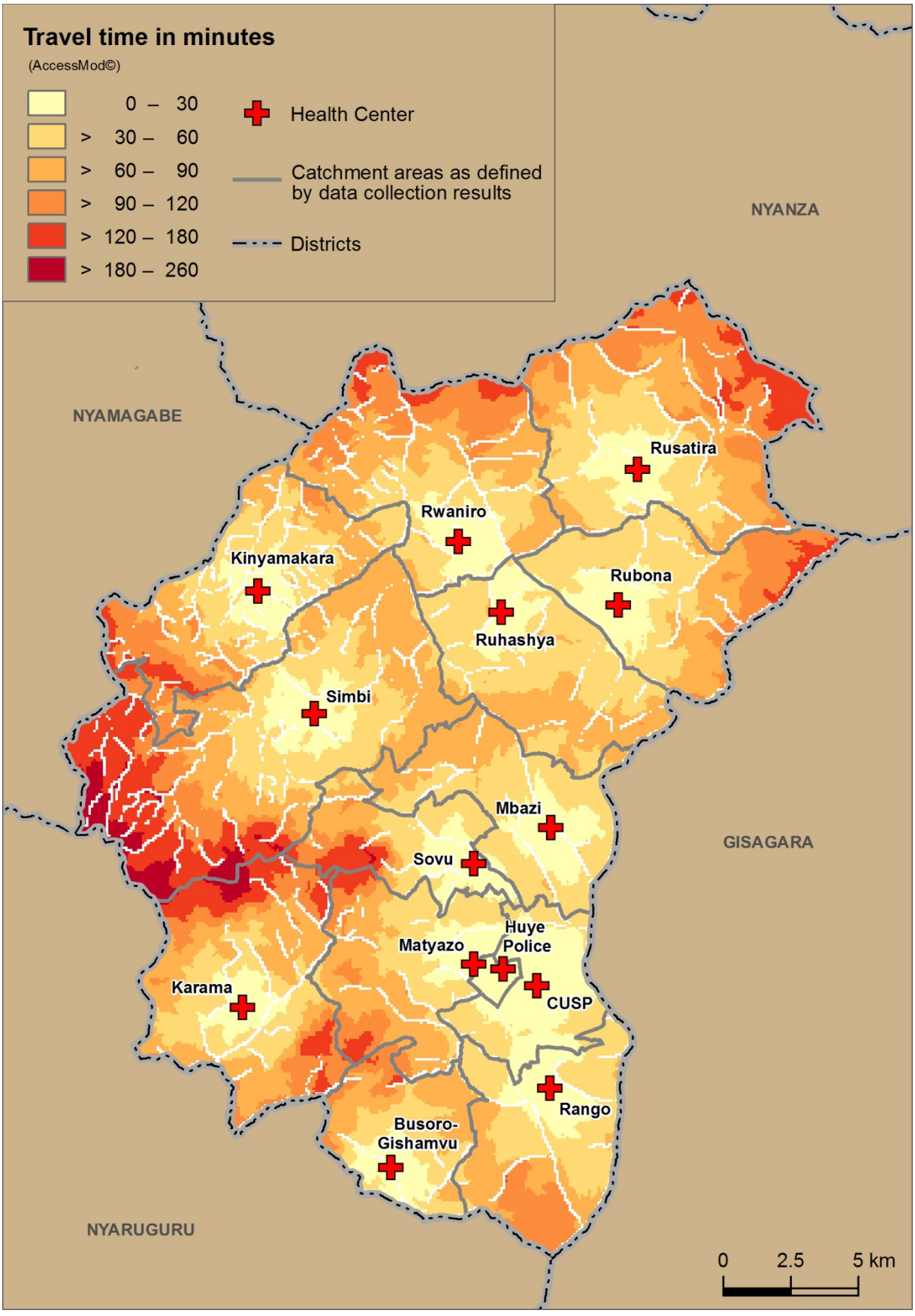

Figure 5.28: Results in AccessMod for ArcGIS 9.3 showing travel time distances to health centers, here with rivers included into the analysis

5.4.4 Huff model

The "Huff model" Script Tool used in ArcGIS 10 allows the consideration of an attractiveness factor for calculating market areas based on Euclidean or road network distances. Although in HUFF's definition a bigger distance decay parameter is said to reduce the market area (HUFF, 1964:37), with the Huff model script tool a bigger value defines the market areas more equally and more realistically. With road network distances boundaries between market areas shift slightly. The map (Figure 5.29) shows the best result for this method with straight line distances, a distance decay parameter with the value 3, and the weighted attractiveness factor (scenario 5, see section 4.2.10.5 for details). While market areas of Rusatira, Rango and Kinyamakara match comparably well with the actual utilization, the areas of Huye Police and Sovu are enlarged significantly. Compared to the administratively assigned areas again Huye Police but also Matyazo HC receive bigger areas which results in higher estimates of population to be served (see Table 5.9**,** Table 5.10, and Table 5.11). In the average the result of population estimates is compared to the administratively assigned areas on third position. Possibly, further testing on the attractiveness factor could lead to better results. This includes the investigation on not yet included parameters like the perceived quality of care for example but also on the weighting of the parameters.

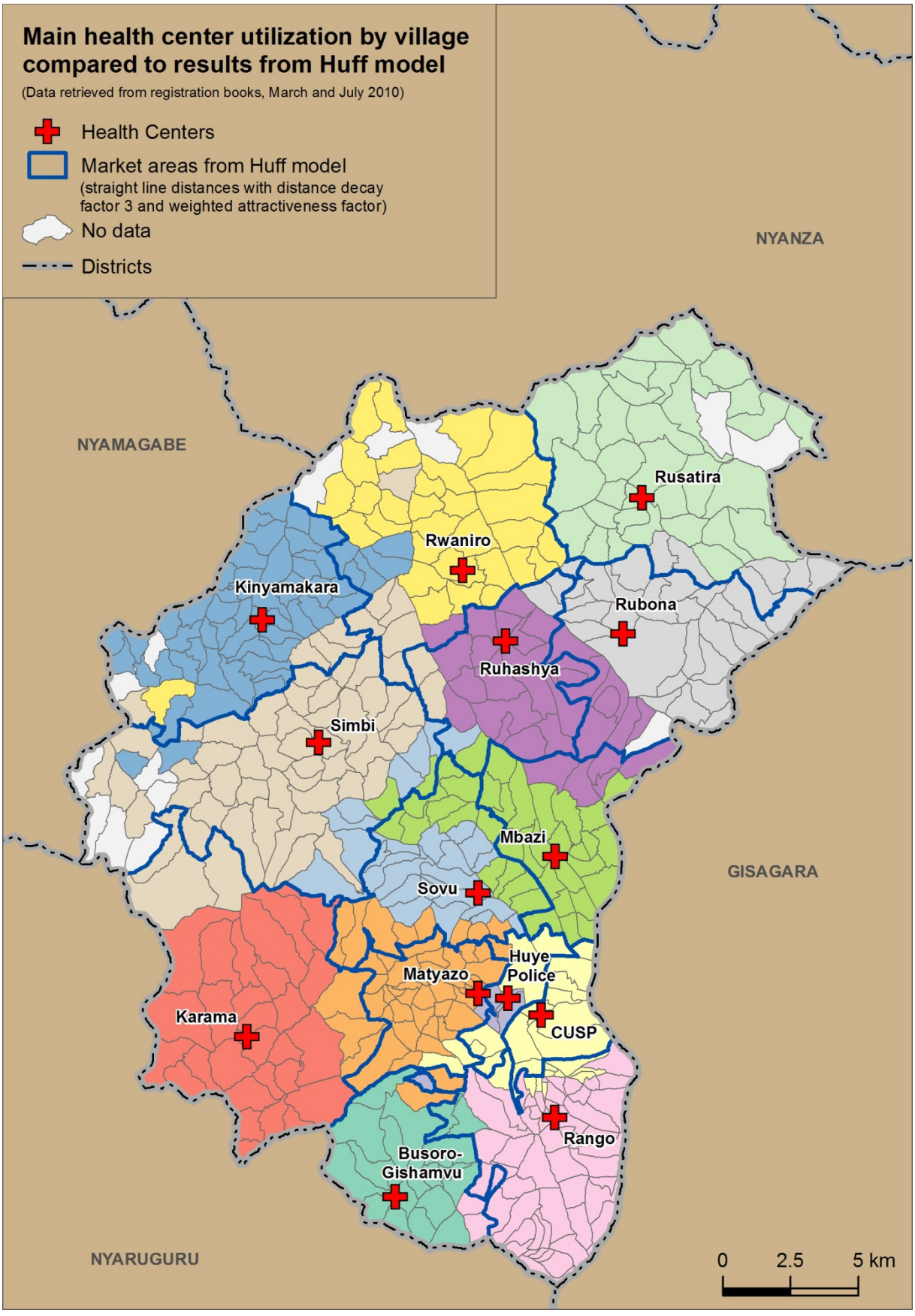

Figure 5.29: Results from the Huff model script tool in comparison to the main utilization of health centers by villages

5.4.5 Network Analysis

Network analysis was performed on basis of the road network received from NISR (NISR, 2012c) improved by trails digitized from aerial pictures and orthophotos (NLC, 2008a, 2008b). The Closest-Facility-Analysis calculates the distances from village centroids to health centers and defines this way a catchment area for each health center (see Figure 5.30). Including the health centers in the neighboring districts in the analysis, 77 of the 508 villages in Huye District are closer to a health center in another district which concerns about 15 % of the population. Still about 23 % of the population are not within a distance of 5 km to the next health center (see Figure 5.31). The analysis underlines the message of Figure 5.22 that patients not necessarily attend the closest health center but that they accept even longer travel distances to attend a certain health center, either because they feel obliged to attend their administratively assigned health center or because another health center is more attractive. The first case is for example well visible in the area of Ruhashya HC where the actual utilization matches almost perfectly the administratively assigned area (see Table 5.4, and Figure 5.16). Those areas far from the health center would be closer to Rubona or Mbazi HC but patients still attend Ruhashya HC. However, it should be kept in mind that from each of these villages less than five patients have been registered.

Table 5.4: Estimations of served population per health center for network analysis results

	Method			
Health center	**Administrative**	**Catchment areas (reg. books)**	**Closest-Facility-Analysis**	**Service-Area-Analysis**
Busoro-Gishamvu	14139	11496	13178	13787
CUSP	5222	20265	7915	7751
Huye Police	3963	3963	9475	9787
Karama	16448	16447	17285	16956
Kinyamakara	24473	23763	23972	23295
Matyazo	8296	25212	17571	18134
Mbazi	30465	27462	23011	22893
Rango	46067	32803	38518	37751
Rubona	18448	18448	23021	21732
Ruhashya	22061	19976	14879	15643
Rusatira	26516	26515	29497	29577
Rwaniro	23241	23241	24268	24495
Simbi	47449	44890	42561	43779
Sovu	20770	13070	22399	21918
Total	**307558**	**307558**	**307550**	**307498**

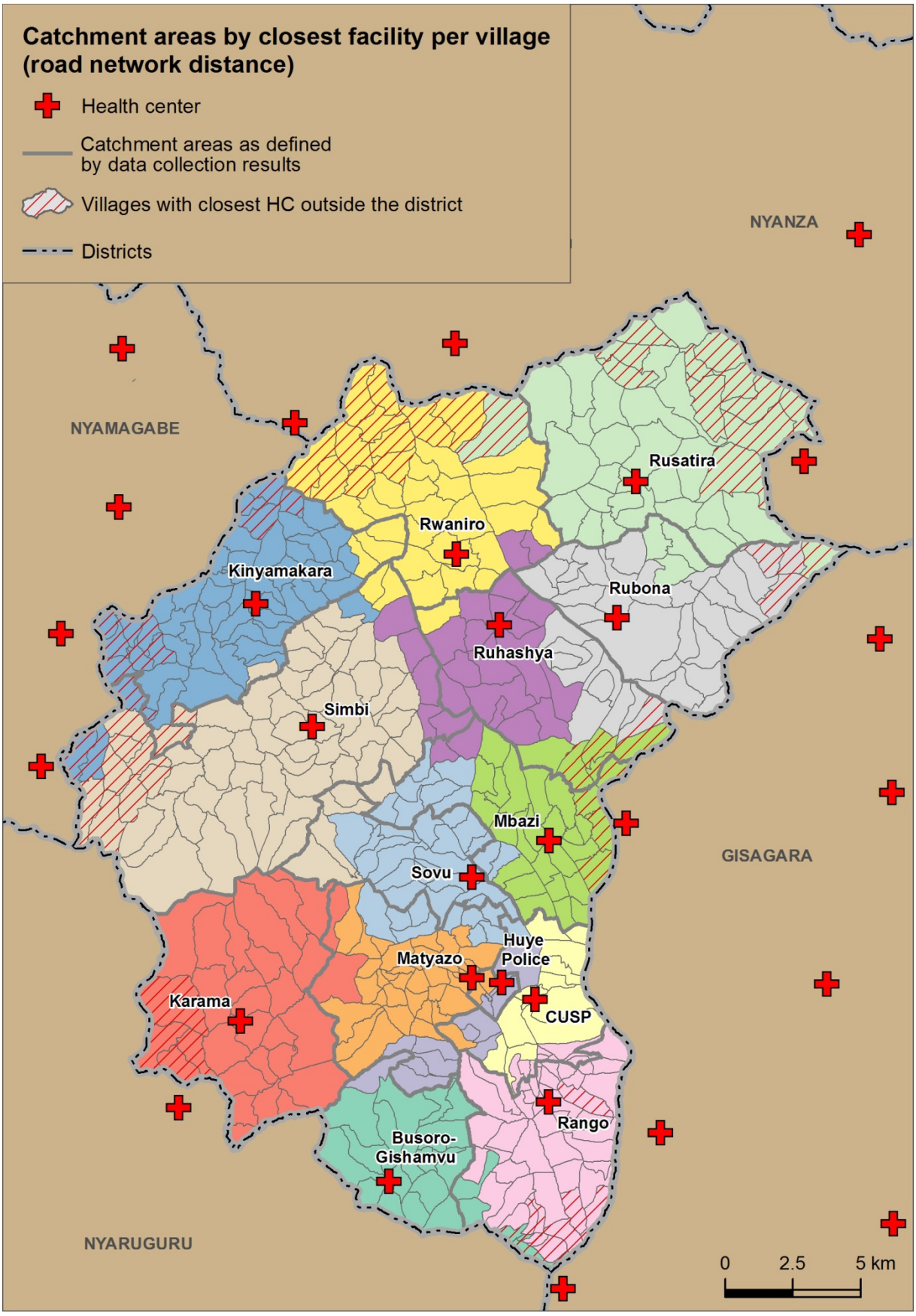

Figure 5.30: Catchment areas by closest health center based on road network distances between village points and health centers

The Service-Area-Analysis calculates areas that are within given travel distances based on the road network. Results show that about 58 % of the study area are within a 5 km distance to the next health center in Huye District, covering about 67 % of the population. About 30 % of the population have to travel more than 5 km by road network to reach the closest health center. About 5 % of the area are more than 10 km away from the next health center which concerns about 3 % of the population (see Figure 5.31).

Service-Area-Analysis simplifies the areas that are calculated to be within the given travel distances. Calculating the served population on basis of the dasymetric population distribution map instead of using villages, the estimations can be assumed to be more precise than via the Closest Facility analysis but differences are only small (see Table 5.4).

Network analysis assumes that patients are mainly using the roads and trails. The outcomes of this method are highly dependent on the quality of the road network. This is on the one hand influenced by the quantity of roads and trails. It can be assumed that patients also use trails that have not been captured by digitizing. On the other hand, the quality of the road network is depending on the topology of the data: Are the roads and trails correctly linked to each other? Only one missing connection between two edges in the network can result in the calculation of a longer route. Another important factor is the position of "incidents": the locations used for calculating routes to health centers. In this case points of villages serve as incidents for the analysis. In the data received from NISR the points have been placed as centroids of village polygons without consideration of the population distribution within the area. Thus only a shift by 500 meters in one or the other direction can influence the allocation of the village to a health center. It occurs that a village seems to be closer to one health center while the distance via the road network from the given village point is shorter to another health center. This is for example visible for one village close to Rango HC for which the road distance is shorter to the health center in the neighboring district (see Figure 5.30). Due to possible errors in the network the found route via the network is not necessarily the shortest route and of course it is not clear if this is the route a patient would use.

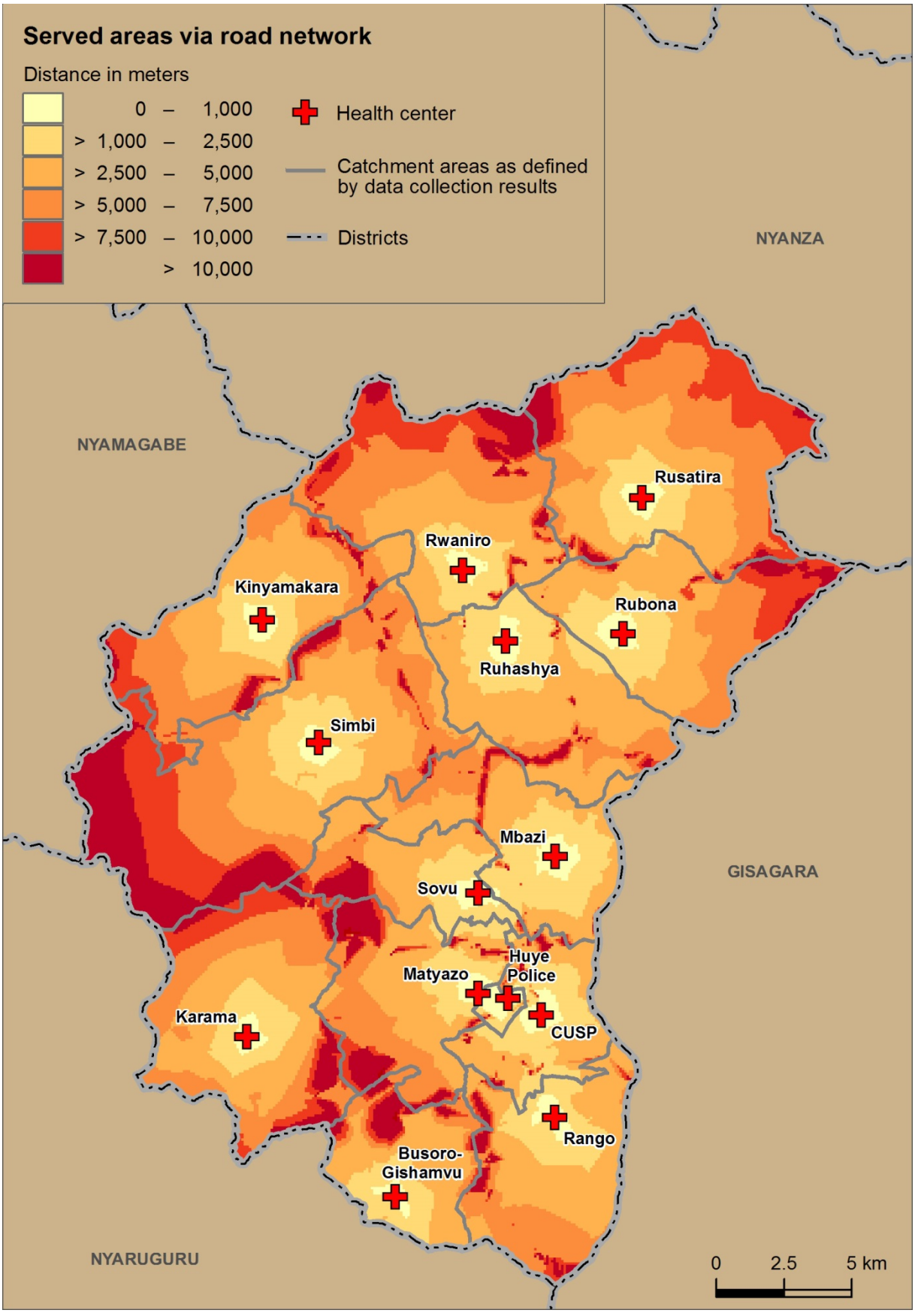

Figure 5.31: Service areas by road network distances

5.4.6 Distance utilization indices

The following figure shows the Distance Utilization Indices (DUI) based on TANSER et al. (2001) that indicates with a value close to 1 a good utilization by patients from the administratively assigned zone (see Figure 5.32). On the left only the patients coming from the district are included into the calculation, on the right also all other patients. In contrast to TANSER and his colleagues who only calculated with Euclidean distances, for this study it was also calculated taking road network distances into account. Both maps show clearly the good utilization from the concerned zone for most of the health centers. For CUSP the index is the lowest, while for Busoro-Gishamvu the high utilization from the neighboring district reduces the index to 0.51 for road distances and to 0.47 for Euclidean distances. For all calculations Kinyamakara receives the highest index.

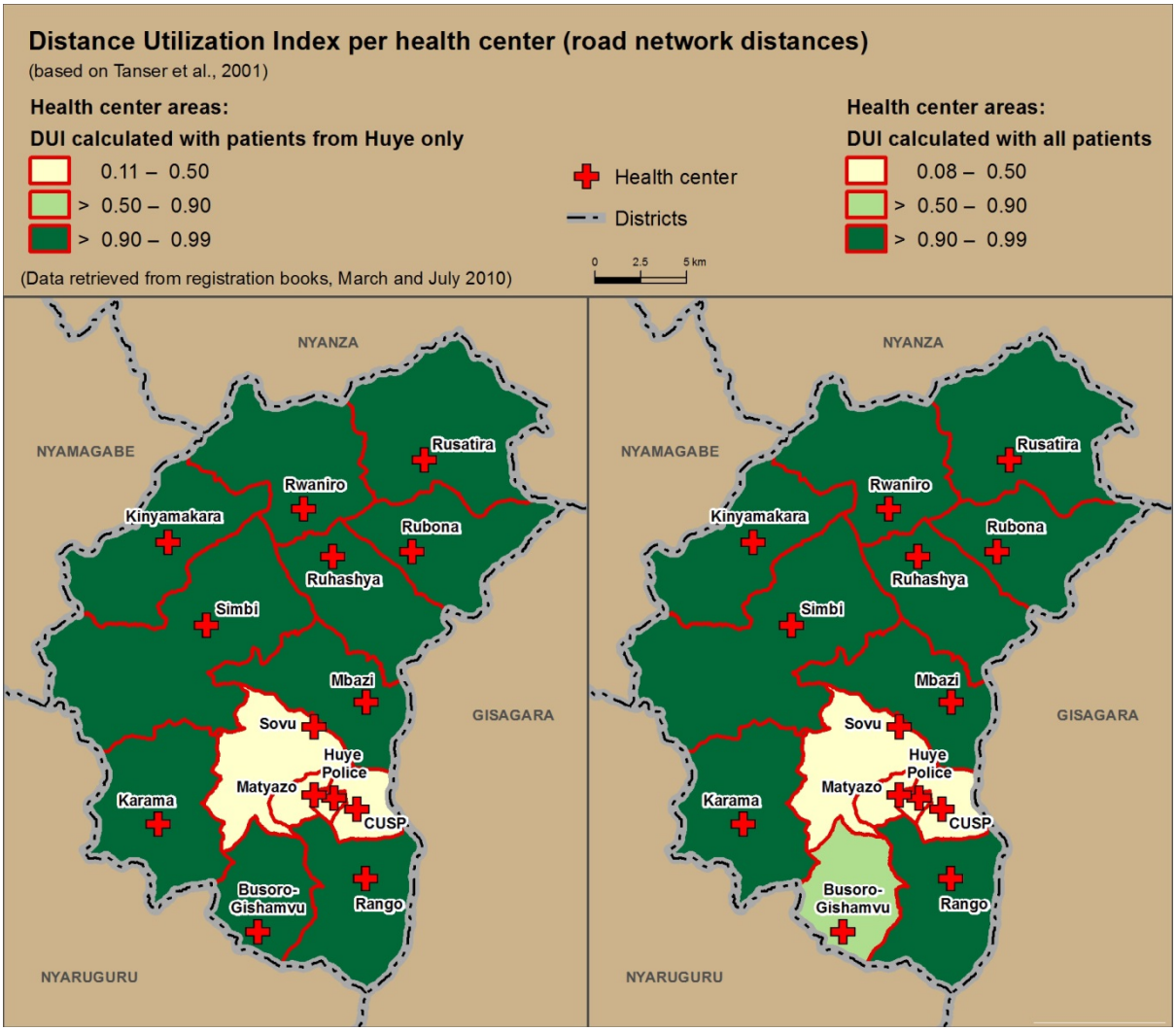

Figure 5.32: The DUI (based on TANSER et al., 2001) calculated with road network distances for the health centers in Huye District

Although the DUI gives a good picture of the health center utilization in general, a more detailed impression is given with an index calculated for villages. The Euclidean Distance Index (EDI) gives the ratio of the Euclidean distances to the mainly used health center and the administratively assigned health center for each village. Accordingly the Road Distance Index (RDI) shows the ratio considering road distances. A low index indicates that the mainly used health center is much closer to the village than the administratively assigned one. A high index shows that patients from this village are travelling further to the mainly used health center than the administratively assigned health center would be. The maps show only small differences between Euclidean and Road Distance Indices. For both indices about 84 % of the villages receive an index between 0.9 and 1.1. In the region around the area of Matyazo HC a low index is identified which indicates again the poor utilization of Sovu HC by the population from this area (see Figure 5.33).

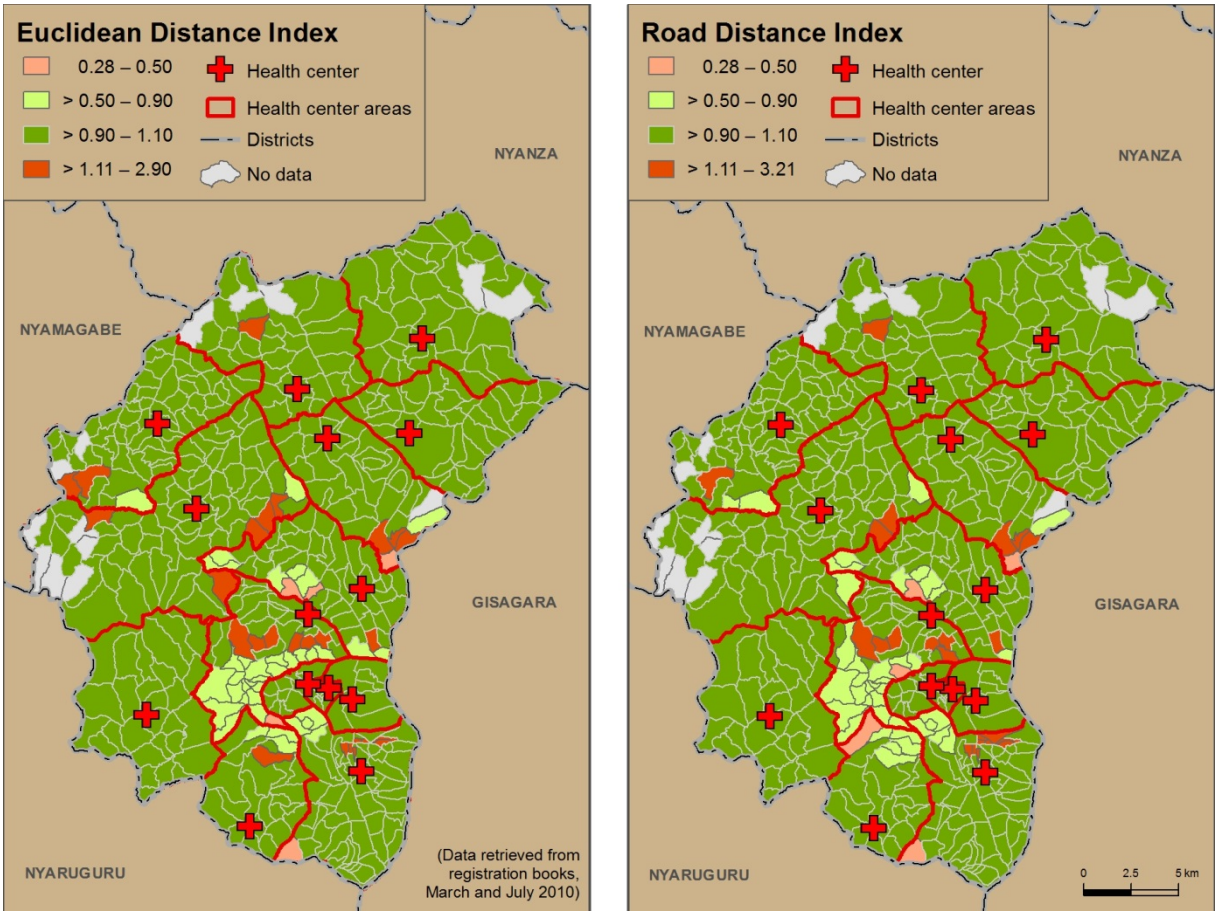

Figure 5.33: Euclidean and Road Distance Index for villages in Huye District (EDI=MaxED/AdminED, RDI=MaxRD/AdminRD)

Table 5.5 shows in detail the utilization by health center and Inclusion Error and Exclusion Error based on TANSER et al. (2006). The Inclusion Error shows the percentage of patients coming from another area than the area assigned to the health center and is comparable to the numbers given for Z, HZ and HD in Table 5.2. They differ slightly because here the patients are limited to the district area and to those villages from outside the district where at least 10 patients were registered (n=26,017). Inclusion Error for Huye only considers patients from Huye District which is best visible for Busoro-Gishamvu HC where the share of patients coming from another district is the highest followed by CUSP Butare HC. The Exclusion Error shows the percentage of patients that did not use the health center that is assigned to their village. It shows what is not well visible in the maps: For example the high share of patients from the area of Huye Police HC that is using CUSP Butare and Matyazo HC; or that almost 30 % from the patients living in the area of Rango HC used CUSP HC in Butare. It additionally underlines the message of previous maps that on the one hand almost 60 % of the patients living in the area of Sovu HC is visiting a different health center, mainly Matyazo but also CUSP Butare. On the other hand Sovu HC receives a high number of patients from the Mbazi HC area which results in high Inclusion and Exclusion Errors for Sovu HC.

Table 5.5: Overview of health center utilization with Exclusion and Inclusion Error based on TANSER et al. (2006)

Total of patients per Health Center		Administratively assigned Health Center															Total of patients	Utilization Z+HD	Utilization HZ	Inclusion Error (percent)	Inclusion Error (percent) (Huye only)
		out of Huye	Busoro-Gishamvu	CUSP Butare	Huye Police	Karama	Kinyamakara	Matyazo	Mbazi	Rango	Rubona	Ruhashya	Rusatira	Rwaniro	Simbi	Sovu					
Used HC	Busoro-Gishamvu	897	1445	1						55							2398	953	56	39.7	2.3
	CUSP Butare	562	14	661	130	4	3	51	347	1193	3	15	4		11	162	3160	2499	1937	79.1	61.3
	Huye Police	2	18	9	382			79	30	43						39	602	220	218	36.5	36.2
	Karama	17				1076									3	6	1102	26	9	2.4	0.8
	Kinyamakara						1884							1	4		1889	5	5	0.3	0.3
	Matyazo	1	31	6	116	9		1439	6	84					1	589	2282	843	842	36.9	36.9
	Mbazi						1		3473			14			6	20	3514	41	41	1.2	1.2
	Rango		6						1	3310	1	1			1		3320	10	10	0.3	0.3
	Rubona							1	1		1155	11	3				1171	16	16	1.4	1.4
	Ruhashya											2180		3	14		2197	17	17	0.8	0.8
	Rusatira										11	1	1102	1			1115	13	13	1.2	1.2
	Rwaniro						2					1		962	5	1	971	9	9	0.9	0.9
	Simbi						17		2					1	1003		1023	20	20	2.0	2.0
	Sovu								525						156	592	1273	681	681	53.5	53.5
Total of patients		1479	1514	677	628	1089	1907	1570	4385	4685	1170	2223	1109	968	1204	1409	26017	5353	3874	20.6	14.9
Total external utilization		69	16	246	13	23	131	912	1375	15	43	7	6	201	817						
Exclusion Error (percent)		4.6	2.4	39.2	1.2	1.2	8.3	20.8	29.3	1.3	1.9	0.6	0.6	16.7	58.0						
Villages without reported utilization						2					1	2	3	6							

5.4.7 Own approach: Path distance allocation

This last approach, the path distance allocation analysis, combines elements from previous methods: Basis is the cost layer following the approach of TANSER and his colleagues (2006) which is improved by two different travel speed scenarios based on the study of HUERTA MUNOZ & KÄLLESTÅL (2012). In the attempt to include also the attractiveness of a facility like the Huff model does, this factor is also applied to the cost layer. Additionally the DEM with a vertical factor is included in respect of the hilly terrain like it is also done with the AccessMod extension.

Comparing the four different scenarios, the walking model, the hybrid model, and both adjusted by the attractiveness factor AF2, differences are only small. Especially between the walking and the hybrid model differences are hardly visible, also for those health centers where a comparable high utilization of public transport is reported (see Table 5.6 and Table 5.7). The disparities are best observable for the area of Rwaniro HC between the models with the application of AF2 and without (see Figure 5.34). Here both models without the consideration of AF2 match far better the catchment areas as defined by the data retrieved from registration books. Although for the areas of seven health centers the allocation areas are matching better the reference catchment areas without applying the attractiveness factor (AF2), in the average the results with the integration of the attractiveness factor give much better results (see Table 5.7). This is mainly caused by the smaller estimated catchment area for the Huye Police HC with AF2, where a part of the area is given to Busoro-Gishamvu HC to the south. This leads to a far higher population estimation for Busoro-Gishamvu and to a smaller value for Huye Police, though its population to be served is still far higher estimated with about 180 % both of the administratively assigned population and the population calculated from defined catchment areas (see Table 5.7, percentages below 75 % are highlighted in orange, above 125 % in red).

Applying the attractiveness factor (AF2) to the cost layer results in values that are more difficult to interpret thus area and population estimates for travel distances are based on calculations without the attractiveness factor (see Table 5.8). Also for this approach further research on the impact of rivers and streams on travel times is needed and an improved attractiveness factor would most probably lead to a better result. Reported travel times during the survey have not been conclusive enough to serve as a basis for estimating travel speeds. Thus also here more research could improve the results of this approach.

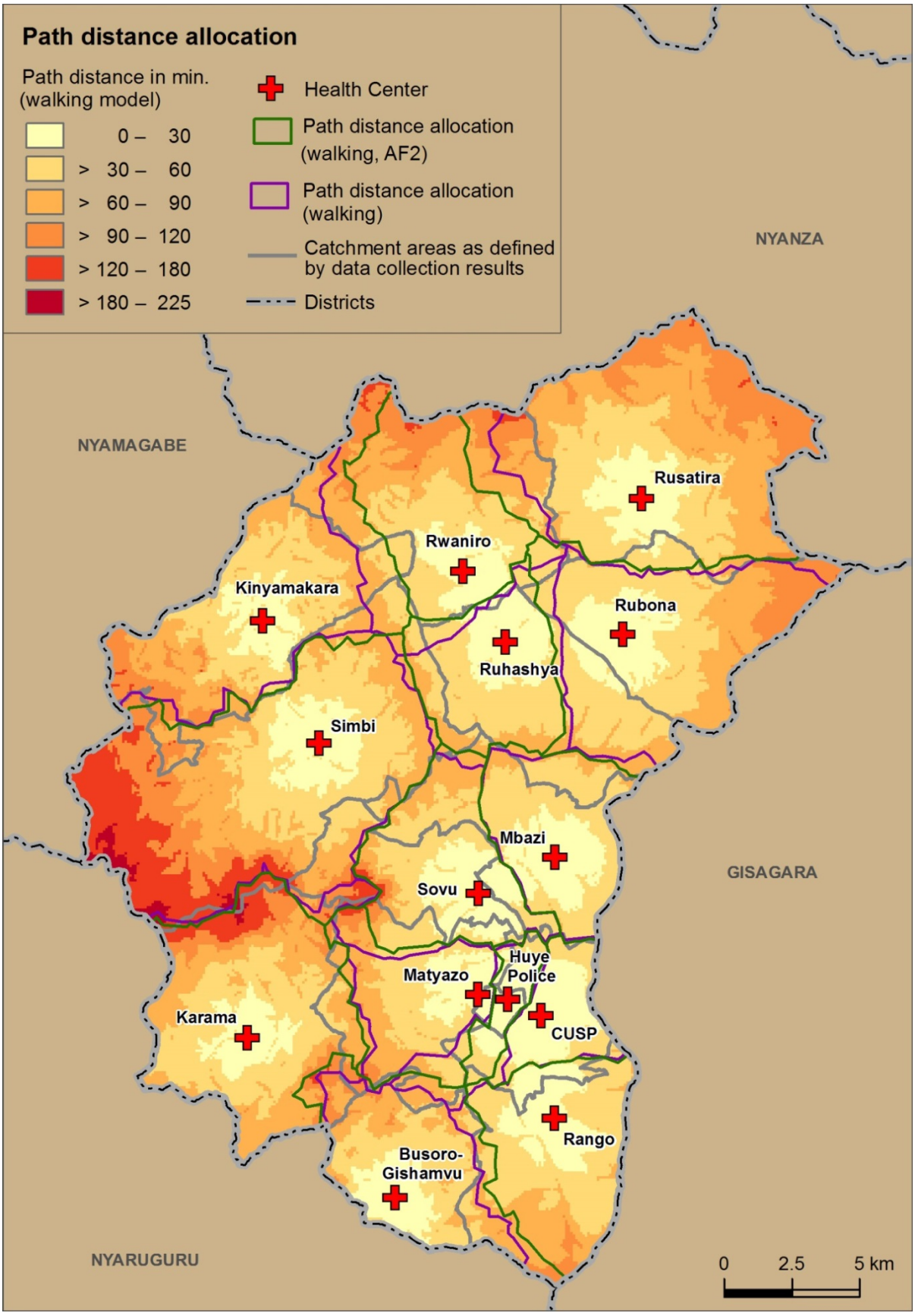

Figure 5.34: Results of the path distance allocation analysis compared to catchment areas defined by data collection results

Table 5.6: Estimations of served population for results from different models in comparison to the administratively assigned population and calculations from registration books

	Method					
Health center	**Admin.**	**Catchment areas (reg. books)**	**Walking model**	**Hybrid model**	**Walking, AF2**	**Hybrid, AF2**
Busoro	14139	11496	12923	14139	17063	18121
CUSP	5222	20265	6844	6707	7389	7284
Huye Police	3963	3963	11140	10954	7226	7333
Karama	16448	16447	17299	17364	16549	16483
Kinyamakara	24473	23763	21478	21423	30138	30118
Matyazo	8296	25212	16749	16912	20362	19997
Mbazi	30465	27462	20810	20406	20826	20691
Rango	46067	32803	39848	38998	36936	36355
Rubona	18448	18448	22692	23092	26799	26889
Ruhashya	22061	19976	13845	13691	12093	11983
Rusatira	26516	26515	29587	29653	29907	30010
Rwaniro	23241	23241	24364	24355	13269	13267
Simbi	47449	44890	46263	46214	46246	46213
Sovu	20770	13070	23712	23557	22666	22717
Total	**307558**	**307558**	**307550**	**307462**	**307470**	**307459**

Table 5.7: Comparison of population estimates to the population calculated for catchment areas retrieved from registration books

	Method			
Health center	**Walking model**	**Hybrid model**	**Walking AF2**	**Hybrid AF2**
Busoro	112.4	123.0	148.4	157.6
CUSP	33.8	33.1	36.5	35.9
Huye Police	281.1	276.4	182.3	185.0
Karama	105.2	105.6	100.6	100.2
Kinyamakara	90.4	90.2	126.8	126.7
Matyazo	66.4	67.1	80.8	79.3
Mbazi	75.8	74.3	75.8	75.3
Rango	121.5	118.9	112.6	110.8
Rubona	123.0	125.2	145.3	145.8
Ruhashya	69.3	68.5	60.5	60.0
Rusatira	111.6	111.8	112.8	113.2
Rwaniro	104.8	104.8	57.1	57.1
Simbi	103.1	102.9	103.0	102.9
Sovu	181.4	180.2	173.4	173.8
Total	100.0	100.0	100.0	100.0
Average	247.3	243.3	145.9	149.1

5.5 Calculation of served areas and population per health center

Table 5.8 shows that estimations of served areas and served population within the recommended 5 km or one hour travel distance differ highly depending on the used method. While the Euclidean distance models give the best estimates, the values are still below the coverage of 91 % as reported by the district (UWIZEYE, Huye District, 2011). Compared to the results of other methods, Euclidean distances overestimate the served population by more than 20 % which is comparable to findings of NOOR and colleagues in Kenya (NOOR et al., 2006:192).

Table 5.8: Comparison of served area and served population in a distance of 5 km or in an estimated travel time distance of 1 hour

	Method	Area	Population
5 km travel distance	Within 5 km Euclidean distance (nearest method/buffer, NOOR et al., 2004)	86.4 %	89.3 %
	Within 5 km zone from IDW interpolation (NOOR et al., 2004)	87.6 %	89.5 %
	Within 5 km road travel distance (Service-Area-Analysis)	57.6 %	67.1 %
1 hour travel time	AccessMod (with rivers)	49.7 %	60.2 %
	Cost Allocation (TANSER et al., 2006)	43.8 %	53.8 %
	Path Distance Allocation (walking model)	57.4 %	67.7 %
	Path Distance Allocation (hybrid model)	58.5 %	68.7 %

Also calculations of the served population per health center vary highly between the different methods. Compared to the served population calculated per health center area based on census data from 2012, the catchment areas based on data from registration books represent the best the administratively assigned areas (see Table 5.9 and Table 5.10**;** red marked values show highly overestimated populations with more than 125 %, orange highly underestimated with less than 75 %). Partly this is also visible in the maps where the areas match well the administrative boundaries, mainly for those health centers where the areas border a neighboring district. Still, none of the methods can reflect the actually high utilization of CUSP Butare HC while all methods calculate for Huye Police HC about 200 % of the actual population to be served. Compared to former approaches the new approach gives in the average a slightly better result, except of Thiessen polygons.

Table 5.9: Comparison of served population per health center depending on the method

	Method						
Health center	Admin.	Catchment areas (reg. books)	Thiessen polygons	Cost Allocation	Closest Facility	Huff model (Euclidean distances)	Path Distance (walking model, AF2)
Busoro-G.	14139	11496	13703	13617	13178	11993	17063
CUSP	5222	20265	7330	6378	7915	6453	7389
Huye Police	3963	3963	6250	11051	9475	9530	7226
Karama	16448	16447	18956	17482	17285	20151	16549
Kinyamakara	24473	23763	27607	22637	23972	22602	30138
Matyazo	8296	25212	21598	16313	17571	18310	20362
Mbazi	30465	27462	21609	21896	23011	20701	20826
Rango	46067	32803	39437	39239	38518	41361	36936
Rubona	18448	18448	20636	20689	23021	18760	26799
Ruhashya	22061	19976	13826	12473	14879	14457	12093
Rusatira	26516	26515	30653	30670	29497	30030	29907
Rwaniro	23241	23241	23565	25707	24268	28925	13269
Simbi	47449	44890	41340	45887	42561	41774	46246
Sovu	20770	13070	21040	23399	22399	22504	22666
Total	**307558**	**307558**	**307550**	**307438**	**307550**	**307558**	**307470**

Table 5.10: Percentage of census population depending on the method

	Method						
Health center	Admin.	Catchment areas (reg. books)	Thiessen polygons	Cost Allocation	Closest Facility	Huff model (Euclidean distances)	Path Distance (walking model, AF2)
Busoro-G.	100	81	97	96	93	85	121
CUSP	100	388	140	122	152	123	142
Huye Police	100	100	158	279	239	241	182
Karama	100	100	115	106	105	123	101
Kinyamakara	100	97	113	93	98	92	123
Matyazo	100	304	260	197	212	221	245
Mbazi	100	90	71	72	76	68	68
Rango	100	71	86	85	84	90	80
Rubona	100	100	112	112	125	102	145
Ruhashya	100	91	63	57	6	66	55
Rusatira	100	100	116	116	111	113	113
Rwaniro	100	100	101	111	104	125	57
Simbi	100	95	87	97	90	88	98
Sovu	100	63	101	113	108	108	109
Total	100	100	100	100	100	100	100.0
Average		127.1	115.7	118.1	118.8	117.4	117.1

Comparing the calculated served population from the GIS based methods to the catchment areas as defined by data from registration books all methods show high differences for the health centers of Busoro-Gishamvu, CUSP Butare, Huye Police, Matyazo and Rwaniro. Also in this case in the average Thiessen polygons give the best results, followed by the path distance allocation analysis considering the walking model and the attractiveness factor AF2.

Table 5.11: Served population in comparison to the calculated catchment areas based on data from registration books in percent (March and July 2010)

	Method						
Health center	**Catchment areas (reg. books)**	**Admin.**	**Thiessen polygons**	**Cost Allocation**	**Closest Facility**	**Huff model (Euclidean distances)**	**Path Distance (walking model, AF2)**
Busoro-G.	100	123	119	118	115	104	148
CUSP	100	26	36	32	39	32	37
Huye Police	100	100	158	279	239	241	182
Karama	100	100	115	106	105	123	101
Kinyamakara	100	103	116	95	101	95	127
Matyazo	100	33	86	65	70	73	81
Mbazi	100	111	78.7	80	84	75	76
Rango	100	140	120	120	117	126	113
Rubona	100	100	112	112	125	102	145
Ruhashya	100	110	69	62	75	72	61
Rusatira	100	100	116	116	111	113	113
Rwaniro	100	100	101	111	104	125	57
Simbi	100	106	92	102	95	93	103
Sovu	100	159	161	179	171	172	173
Total	100	100	100	100	100	100	100
Average		100.8	105.7	112.6	110.8	110.4	108.3

6 Health center utilization in Huye District: Conclusions

The study shows that – depending on the used method – at least 60 % of the district area and accordingly 70 % of the district population live within a distance of about 5 km to the next health center. For all health centers a clear drop of utilization by villages in a road distance of more than 5 km is visible which shows that this value is a valid measure for the spatial access to health care. With the high coverage by health insurance the costs of health care are comparably low, though still patients complain about high costs and are sometimes not able to afford the consultation fees. Only a small share of the patients is using public transport which on the one hand reduces the general cost of transport but on the other hand increases the travel time. The fact that patients are eventually seeking health care at a health center is due to the perceived severity of illness, while the choice for a particular health center seems to depend on several factors, as NOOR and his colleagues (2003) concluded, too. These factors show spatial disparities in the study area.

6.1 Health center choice

In general patients seem to have the impression of not having a choice to which health center they could go for primary health care. Instead they think they have to register their Mutuelle de Santé at the health center in their sector, depending on the service area of the health center:

> *"I am obliged to come here because of the administrative boundary. Save HC is nearest my home."* *[Mbazi, MJ49]*

> *"I come here because it is in my sector but Ruhashya is nearest my resident - but law doesn't permit me to use the nearest health center."* *[Simbi, MJ128]*

While it is true that people should register at only one health center and preferable at the one in their area, they are free to choose the health center to be registered. In fact the patients then have to go to this health center first in order to be covered by the Mutuelle de Santé. Only in case of an emergency they are treated at the next available health center (FISCHER, GTZ, 2010; NTAKIRUTIMANA, Huye District, 2011).

Clearly distance plays an important role as BUOR (2003) already pointed out, but the administrative affiliation of villages to health center areas seem to influence the choice of the health center even more: While 84 % of the patients have been registered at their

administratively assigned health center, only about 80 % of the patients are using the nearest health center (see also Figure 5.21 and Figure 5.22). At this point the impact of rivers and streams needs some more investigation: often they have been used to establish sector boundaries and thus it is not clear if the river or the administrative boundary itself plays the bigger role in preventing patients to use the next health center.

Nevertheless obviously some health centers are more popular than others: Matyazo HC attracts a high portion of patients from another area although the opinions about the service and customer care are mixed. While for a share of patients the choice of using Matyazo HC might be caused by the higher distance to another health center, in those areas where the distance to another health center is the same or even shorter, the reason for choosing Matyazo is not clear. Accessibility might play a role since the health center is located at a district road where public transport is available. The attractiveness of CUSP Butare HC can be explained by the good reputation of the health center itself but also of the district hospital. Patients prefer to be transferred to the district hospital in Butare instead to those in different districts. But also the good accessibility as well as having a job in the urban area might influence the choice of using CUSP Butare HC. This shows that at least a certain share of patients seems to be aware of having a choice which is clearly visible in the Inclusion Error (see Table 5.5) and in these comments:

> *"Simbi (my home) is the best but I came here [Rubona] because it's near to the work."*
> *(she has two mutuelle, she can either go to Simbi or Rubona HC)* *[Rubona, KB100]*

> *"I have access to two health centers (Rusatira and Rubona), the distance is the same, but I chose Rubona because they provide good services."* *[Rubona, KB94]*

To improve the effective spatial access for the population, the information about regulations for the registration of Mutuelle de Santé and its utilization at health centers need to be communicated better to the population. Although the accessibility via a paved road might be a reason for the above mentioned health centers to receive more patients from other areas, it cannot be seen as an influencing factor in general as has been shown for other health centers like Rusatira, Rubona or Rango.

6.2 Modeling of catchment areas

Modeling in GIS shows the difficulties with automatic progresses. None of the methods is able to model the catchment areas for health centers in Huye District in a way that meets the actual utilization. Comparing the served population calculated for each model with the population based on catchment areas from registration books, in the average Thiessen polygons and the path distance allocation analysis represents the best the served population per health center. Visually the path distance allocation method using an approach with a modified walking speed formula gives slightly better results than former approaches based on cost allocation analysis (TANSER et al., 2006). Estimations of the served area by one hour travel time give for the walking model as well as for the hybrid model higher results for the area itself as well as for the served population than the cost distance allocation analysis and also the AccessMod based approach. Since they lie between the most positive estimations with Euclidean distances and the most negative estimations on basis of the cost distance allocation analysis, path distance allocation results can be assumed to get the closest to reality. Possibly results could be improved if further research is done on the implementation of an attractiveness factor.

In terms of estimating catchment areas the main mode of travel does not play a role but in regards of estimating the area and the population that can reach a health center within a certain time it certainly is of importance that patients mainly travel by foot and that public transport is hardly available in rural areas of the country. Due to the hilly terrain and the high coverage by rain fed plantations it can be assumed that patients mainly use roads and trails like they have been digitized for road network analysis. Still, the fact that methods based on Euclidean distances or in case of the path distance allocation method, a walking model that allows to walk between roads or trails, give comparably better results than methods based on road network distances, allows the conclusion that Euclidean distances represent well walking distances as TANSER and his colleagues (2006) already assumed. However, the high difference between estimations on served areas and served population from Euclidean distances and path distance allocation analysis results show that further investigation is needed on the actual travel speed. Comparing the results from different methods it can be estimated that the population that can reach a health center within one hour travel time or from a distance of less than 5 km is with probably between 60 and 80 % far below the official estimations of 91 % coverage (UWIZEYE, Huye District, 2011).

6.3 Transferability of results

Health facilities in Butare town have an high force of attraction and thus result in a partly high utilization from outside the district. This was visible for CUSP Butare HC but also for Busoro-Gishamvu. Here on the one hand the high distance to the next available health center led to a high utilization from the neighboring district but patients also mentioned the hospitals in Butare to be preferable to be referred to. Looking at the HMIS data for 2008, Huye District lay with the district average in the middle field regards utilization from outside the district (MOH, 2010d). One third of the districts report more than 5 % of the patients coming from outside the district which allows the assumption that most of the districts have one or more facilities that are more attractive to patients than facilities in their own district, either because they are closer or otherwise more attractive. The fact that all methods have not been able to predict well the served population, leads to the assumption that the realistic estimation of catchment areas would be as difficult for other districts as it was proofed to be for Huye District.

References

ABELLANA, R; ASCASO, C; APONTE, J; SAUTE, F; NHALUNGO, D; NHACOLO, A. & ALONSO, P. (2008): Spatio-seasonal modeling of the incidence rate of malaria in Mozambique. In: Malaria Journal 7 (228).

ABEL-SMITH, B. & RAWAL, P. (1992): Can the poor afford "free" health services? A case study of Tanzania. In: Health policy and planning 7 (4), 329–341.

ABRAHAMS, N; JEWKES, R. & MVO, Z. (2001): Health care-seeking practices of pregnant women and the role of the midwife in Cape Town, South Africa. In: Journal of Midwifery & Women's Health 46 (4), 240–247.

ADAY, L.A. & ANDERSEN, R. (1974): A framework for the study of access to medical care. In: Health services research 9 (3), 208–220.

ADAY, L.A.; Andersen, R. & Fleming, G.V. (1980): Health care in the US: Equitable for whom? Beverly Hills, CA: Sage.

AKIN, J.S. & HUTCHINSON, P. (1999): Health-care facility choice and the phenomenon of bypassing. In: Health Policy Plan 14 (2), 135–151.

ALBERT, D.P.; Gesler, W.M. & Levergood, B. (2000): Spatial analysis, GIS, and remote sensing applications in the health sciences. Chelsea, MI: Ann Arbor Press.

AMER, S. (2007): Towards Spatial Justice in Urban Health Services Planning. A spatial-analytic GIS-based approach using Dar es Salaam, Tanzania as a case study. Utrecht: University Utrecht.

ANDERSEN, R. (1968): A behavioral model of families' use of health services: Center for Health Administration Studies, University of Chicago.

ANDERSEN, R. & ADAY, L.A. (1978): Access to Medical Care in the U.S.: Realized and Potential. In: Medical Care 16 (7), 533–546.

ANDERSEN, R.M. (1995): Revisiting the behavioral model and access to medical care: Does it matter? In: Journal of Health and Social Behaviour 36 (1), 1–10.

ANDERSEN, R. & NEWMAN, J.F. (1973): Societal and individual determinants of medical care utilization in the United States. In: Milbank Memorial Fund quarterly 51 (1), 95–124.

ANNIS, S. (1981): Physical access and utilization of health services in rural Guatemala. In: Social science and medicine 15 (D), 515–523.

ARBOLEDA, S; JARAMILLO-O, N. & PETERSON, A.T. (2009): Mapping environmental dimensions of dengue fever transmission risk in the Aburrá Valley, Colombia. In: International journal of environmental research and public health 6 (12), 3040–3055.

ATTING, I.A. & EGWU, I.N. (1991): Indicators of accessibility to primary health care coverage in rural Odukpani, Nigeria. In: Asia Pac J Public Health 5 (3), 211–216.

AYENI, B; RUSHTON, G. & MCNULTY, M.L. (1987): Improving the geographical accessibility of health care in rural areas: a Nigerian case study. In: Soc Sci Med 25 (10), 1083–1094.

BAKEERA, S.K; WAMALA, S.P; GALEA, S; STATE, A; PETERSON, S. & PARIYO, G.W. (2009): Community perceptions and factors influencing utilization of health services in Uganda. In: Int J Equity Health 8, 25.

BALEN, J; LIU, Z.-C; MCMANUS, D.P; RASO, G; UTZINGER, J; XIAO, S.-Y; YU, D.-B; ZHAO, Z.-Y. & LI, Y.-S. (2013): Health access livelihood framework reveals potential barriers in the control of schistosomiasis in the Dongting Lake area of Hunan Province, China. In: PLoS neglected tropical diseases 7 (8), e2350.

BARNETT, R. & BARNETT, P. (2009): Health Systems and Health Services. In: KITCHIN, R. & THRIFT, N. (Eds.), International Encyclopedia of Human Geography. Oxford: Elsevier, 58–70.

BARRETT, F.A. (2000): Disease & geography: the history of an idea. Geographical monographs 23. Toronto: York University - Atkinson College.

BASINGA, P; GERTLER, P.J; BINAGWAHO, A; SOUCAT, A.L.B; STURDY, J.R. & VERMEERSCH, C. (2010): Paying Primary Health Care Centers for Performance in Rwanda. In: The World Bank, Policy Research Working Paper Series 5190. — Online: http://ssrn.com/abstract=1543049 (accessed: 2013-03-15).

BASINGA, P; GERTLER, P.J; BINAGWAHO, A; SOUCAT, A.L.B; STURDY, J. & VERMEERSCH, C.M.J. (2011): Effect on maternal and child health services in Rwanda of payment to primary health-care providers for performance: an impact evaluation. In: The Lancet 377 (9775), 1421–1428.

BASINGA, P; SEKABARAGA, C. & SOUCAT, A. (2008): Scaling up innovation in services delivery of Primary Health Care Case of Rwanda. Prince Mahidol Award Conference: 30 January-2 February 2008. Bangkok.

BATWARE, B. (2012): Rwandan Ethnic Conflicts. A historical look at root causes. European Peace University, Austria. — Online: http://acuns.org/wp-content/uploads/2012/06/RwandanConflictRootCauses.pdf (accessed: 2014-09-04).

BBC NEWS (2011): Rwanda: How the genocide happened (2011-05-17). — Online: http://www.bbc.co.uk/news/world-africa-13431486 (accessed: 2014-09-04).

BENNETT, D. (2005): Replacing positivism in medical geography. In: Social science & medicine (1982) 60 (12), 2685–2695.

BEYERS, N; GIE, R.P; ZIETSMAN, H.L; KUNNEKE, M; HAUMAN, J; TATLEY, M. & DONALD, P.R. (1996): The use of a geographical information system (GIS) to evaluate the distribution of tuberculosis in a high-incidence community. In: South African Medical Journal 86 (1), 40–44.

BINAGWAHO, A; KYAMANYWA, P; FARMER, P.E; NUTHULAGANTI, T; UMUBYEYI, B; NYEMAZI, J.P; MUGENI, S.D; ASIIMWE, A; NDAGIJIMANA, U; LAMPHERE MCPHERSON, H; NGIRABEGA, J.d.D; SLINEY, A; UWAYEZU, A; RUSANGANWA, V; WAGNER, C.M; NUTT, C.T; ELDON-EDINGTON, M; CANCEDDA, C; MAGAZINER, I.C. & GOOSBY, E. (2013): The Human Resources for Health Program in Rwanda — A New Partnership. In: N Engl J Med 369 (21), 2054–2059.

BIRKIN, M., Clarke, G; Clarke, M.P. & Wilson, A. (1996): Intelligent GIS. Location decisions and strategic planning. Cambridge [UK]: GeoInformation International.

BLACK, M; EBENER, S; NAJERA AGUILAR, P; VIDAURRE, M. & EL MORJANI, Z. (2004): Using GIS to Measure Physical Accessibility to Health Care. — Online: http://www.who.int/kms/initiatives/Ebener_et_al_2004a.pdf (accessed: 2013-04-12).

BLANFORD, J.I; KUMAR, S; LUO, W. & MACEACHREN, A.M. (2012): It's a long, long walk: accessibility to hospitals, maternity and integrated health centers in Niger. In: International journal of health geographics 11, 24.

BOGART, L.M; CHETTY, S; GIDDY, J; SYPEK, A; STICKLOR, L; WALENSKY, R.P; LOSINA, E; KATZ, J.N. & BASSETT, I.V. (2013): Barriers to care among people living with HIV in South Africa: contrasts between patient and healthcare provider perspectives. In: AIDS care 25 (7), 843–853.

BOUCHET-SAULNIER, F. (1994): Mission Rwanda. Medicins sans Frontieres. — Online: http://speakingout.msf.org/en/node/607 (accessed: 2014-06-24).

BRAECKMAN, C. (1994): Rwanda, histoire d'un génocide. Paris: Fayard.

BROWN, T; MCLAFFERTY, S. & MOON, G. (2010): Introduction to Health and Medical Geography. In: BROWN, T., MCLAFFERTY, S. & MOON, G. (Eds.), A Companion to Health and Medical Geography, 1–11.

BUCHANAN, R.J; STUIFBERGEN, A; CHAKRAVORTY, B.J; WANG, S; ZHU, L. & KIM, M. (2006): Urban/rural differences in access and barriers to health care for people with multiple sclerosis. In: J Health Hum Serv Adm 29 (3), 360–375.

BUOR, D. (2003): Analysing the primacy of distance in the utilization of health services in the Ahafo-Ano South district, Ghana. In: The International journal of health planning and management 18 (4), 293–311.

BUTSCH, C. (2011): Zugang zu Gesundheitsdienstleistungen. Barrieren und Anreize in Pune, Indien. Stuttgart: Steiner.

BYFORD-RICHARDSON, L; WALKER, M; MUCKLE, W; SPRAGUE, A; FERGUS, S; RENNICKS WHITE, R. & DICK, B. (2013): Barriers to access of maternity care in Kenya: a social perspective. In: Journal of obstetrics and gynaecology Canada 35 (2), 125–130.

CANTWELL, N. (1997): Starting from Zero: The promotion and protection of children's rights in post-genocide Rwanda, July 1994-December 1996. UNICEF International Child Development Centre. Florence, Italy. — Online: http://EconPapers.repec.org/RePEc:ucf:innins:innins97/1 (accessed: 2014-06-24).

CECCATO, P. (2006): Development of Malaria Early Warning System (MEWS) using Remote Sensing and Geographical Information Systems. — Online: http://www.isse.ucar.edu/climatehealth/doc/Publications.Pg/Abstract.Ceccato.pdf (accessed: 2014-02-18).

CHAMBERS, R. (1995): Poverty and livelihoods: whose reality counts? In: Environment and Urbanization 7 (1), 173–204.

CHANG, A.Y; PARRALES, M.E; JIMENEZ, J; SOBIESZCZYK, M.E; HAMMER, S.M; COPENHAVER, D.J. & KULKARNI, R.P. (2009): Combining Google Earth and GIS mapping technologies in a dengue surveillance system for developing countries. In: International journal of health geographics 8, 49.

CINNAMON, J; SCHUURMAN, N. & CROOKS, V.A. (2008): A method to determine spatial access to specialized palliative care services using GIS. In: BMC Health Services Research 8, 140.

CLARK, P. & Kaufman, Z.D. (2009): After genocide. Transitional justice, post-conflict reconstruction and reconciliation in Rwanda and beyond. New York: Columbia University Press.

COMFORT, A.B; PETERSON, L.A. & HATT, L.E. (2013): Effect of health insurance on the use and provision of maternal health services and maternal and neonatal health outcomes: a systematic review. In: Journal of health, population, and nutrition 31 (4 Suppl 2), 81–105.

COMMISSION ON SOCIAL DETERMINANTS OF HEALTH (CSDH)(2008): Closing the gap in a generation: health equity through action on the social determinants of health. Final Report of the Commission on

Social Determinants of Health. — Online: http://whqlibdoc.who.int/publications/2008/9789241563703_eng.pdf?ua=1 (accessed: 2014-02-27).

DAMBACH, P; MACHAULT, V; LACAUX, J.-P; VIGNOLLES, C; SIÉ, A. & SAUERBORN, R. (2012): Utilization of combined remote sensing techniques to detect environmental variables influencing malaria vector densities in rural West Africa. In: International journal of health geographics 11, 8.

DEICHMANN, U. (1997): Accessibility indicators in GIS. In: Department for Economic and Social Information and Policy Analysis. United Nations Statistics Division 24.

DHILLON, R.S; BONDS, M.H; FRADEN, M; NDAHIRO, D. & RUXIN, J. (2012): The impact of reducing financial barriers on utilisation of a primary health care facility in Rwanda. In: Global public health 7 (1), 71–86.

DICTIONARY.COM (n.d.): access . — Online: http://dictionary.reference.com/browse/access?s=t (accessed: 2015-04-13).

DONABEDIAN, A. (1972): Models for organizing the delivery of personal health services and criteria for evaluating them. In: Milbank Memorial Fund quarterly 50 (4,2), 103–154.

EARICKSON, R. (2009): Medical Geography. In: KITCHIN, R. & THRIFT, N. (Eds.), International Encyclopedia of Human Geography. Oxford: Elsevier, 9–20.

EBENER, S; EL MORJANI, Z; RAY, N. & BLACK, M. (2005): Physical Accessibility to health care: From Isotropy to Anisotropy. In: GIS@development 9 (6), June 2005. — Online: http://www.who.int/kms/initiatives/Ebener_et_al_2005.pdf (accessed: 2013-04-19).

EICHER, C.L. & BREWER, C.A. (2001): Dasymetric Mapping and Areal Interpolation: Implementation and Evaluation. In: Cartography and Geographic Information Science 28 (2), 125–138.

ELNICKI, D.M; MORRIS, D.K. & SHOCKCOR, W.T. (1995): Patient-perceived barriers to preventive health care among indigent, rural Appalachian patients. In: Arch Intern Med 155 (4), 421–424.

ENSOR, T. & COOPER, S. (2004): Overcoming barriers to health service access: influencing the demand side. In: Health Policy Plan 19 (2), 69–79.

ESRI (2012a): Buffer (Analysis). In: ArcGIS 10.1. Help Redlands: Environmental Systems Research Institute.

ESRI (2012b): Create Thiessen Polygons (Analysis). In: ArcGIS 10.1. Help Redlands: Environmental Systems Research Institute.

ESRI (2012c): How cost distance tools work. In: ArcGIS 10.1. Help Redlands: Environmental Systems Research Institute.

ESRI (2012d): What is a network dataset? In: ArcGIS 10.1. Help Redlands: Environmental Systems Research Institute.

EUROPEAN COMMISSION (2010): Travel time to major cities: A global map of Accessibility . — Online: http://bioval.jrc.ec.europa.eu/products/gam/sources.htm (accessed: 2013-11-26).

FEINSTEIN, L; DIMOMFU, B.L; MUPENDA, B; DUVALL, S; CHALACHALA, J.L; EDMONDS, A. & BEHETS, F. (2013): Antenatal and delivery services in Kinshasa, Democratic Republic of Congo: care-seeking and experiences reported by women in a household-based survey. In: Tropical medicine & international health TM & IH 18 (10), 1211–1221.

FIEDLER, J.L. (1981): A review of the literature on access and utilization of medical care with special emphasis on rural primary care. In: Social Science & Medicine. Part C: Medical Economics 15 (3), 129–142.

FIELD, K.S. & BRIGGS, D.J. (2001): Socio-economic and locational determinants of accessibility and utilization of primary health-care. In: Health & Social Care in the Community 9 (5), 294–308.

FLATER, D. (2010): Market Analysis with the Huff Model - Generic Script Tool (2010-01-26) . — Online: http://arcscripts.esri.com/details.asp?dbid=15999 (accessed: 2013-07-26).

FOTHERINGHAM, A.S. (1981): Spatial Structure and Distance-Decay Parameters. In: Annals of the Association of American Geographers 71 (3), 425–436.

FOX, P.D. (1972): Access to Medical Care for the Poor: The Federal Perspective. In: Medical Care 10 (3).

GAGE, A.J. (2007): Barriers to the utilization of maternal health care in rural Mali. In: Soc Sci Med 65 (8), 1666–1682.

GALLEGO, F.J; BATISTA, F; ROCHA, C. & MUBAREKA, S. (2011): Disaggregating population density of the European Union with CORINE land cover. In: International Journal of Geographical Information Science 25 (12), 2051–2069.

GESLER, W. (1986): The uses of spatial analysis in medical geography: A review. In: Social science and medicine 23 (10), 963–973.

GETHING, P.W; JOHNSON, F.A; FREMPONG-AINGUAH, F; NYARKO, P; BASCHIERI, A; ABOAGYE, P; FALKINGHAM, J; MATTHEWS, Z. & ATKINSON, P.M. (2012): Geographical access to care at birth in Ghana: a barrier to safe motherhood. In: BMC public health 12, 991.

GETHING, P.W; NOOR, A.M; ZUROVAC, D; ATKINSON, P.M; HAY, S.I; NIXON, M.S. & SNOW, R.W. (2004): Empirical modelling of government health service use by children with fevers in Kenya. In: Acta Trop 91 (3), 227–237.

GIEP/OAU (2000): Rwanda - le génocide qu'on aurait pu éviter. Rapport du groupe international d'éminentes personnalités pour enquèter sur le génocide de 1994 au Rwanda et ses conséquences. Union Africaine. Addis Abeba, Ethiopia.

GOINS, R.T; WILLIAMS, K.A; CARTER, M.W; SPENCER, M. & SOLOVIEVA, T. (2005): Perceived barriers to health care access among rural older adults: a qualitative study. In: J Rural Health 21 (3), 206–213.

GOUDGE, J; GILSON, L; RUSSELL, S; GUMEDE, T. & MILLS, A. (2009): Affordability, availability and acceptability barriers to health care for the chronically ill: longitudinal case studies from South Africa. In: BMC Health Serv Res 9, 75.

GRAVES, B.A. (2008): Integrative literature review: a review of literature related to geographical information systems, healthcare access, and health outcomes. In: Perspect Health Inf Manag 5, 11.

GREGORY, D., JOHNSTON, R., PRATT, G., WATTS, M.J. & WHATMORE, S. (Eds.)(2009[5]): The dictionary of human geography. Malden, MA: Blackwell.

GRIFFITH, D.A. (1982): A Generalized Huff Model. In: Geographical Analysis 14 (2), 135–144.

GUAGLIARDO, M.F. (2004): Spatial accessibility of primary care: concepts, methods and challenges. In: Int J Health Geogr 3 (1), 3.

GULLIFORD, M.C. (2002): Availability of primary care doctors and population health in England: is there an association? In: Journal of public health medicine 24 (4), 252–254.

GULLIFORD, M.C; FIGUEROA-MUNOZ, J. & MORGAN, M. (2003): Introduction. In: GULLIFORD, M. & MORGAN, M. (Eds.), Access to health care. London: Routledge, 1–12.

GULLIFORD, M; FIGUEROA-MUNOZ, J; MORGAN, M; HUGHES, D; GIBSON, B; BEECH, R. & HUDSON, M. (2002): What does 'access to health care' mean? In: Journal of health services research & policy 7 (3), 186–188.

HAAN, L. de & ZOOMERS, A. (2005): Exploring the Frontier of Livelihoods Research. In: Development and Change 36 (1), 27–47.

HALL, J.J. & TAYLOR, R. (2003): Health for all beyond 2000: the demise of the Alma-Ata Declaration and primary health care in developing countries. In: The Medical Journal of Australia 178 (1), 17–20.

HANSON, S. (2009[5]): accessibility. In: GREGORY, D., JOHNSTON, R., PRATT, G., WATTS, M.J. & WHATMORE, S. (Eds.), The dictionary of human geography. Malden, MA: Blackwell, 2–3.

HAYNES, R. (2003): Geographical access to health care. In: GULLIFORD, M. & MORGAN, M. (Eds.), Access to health care. London: Routledge, 13–35.

HEARD, N.J; LARSEN, U. & HOZUMI, D. (2004): Investigating access to reproductive health services using GIS: proximity to services and the use of modern contraceptives in Malawi. In: African journal of reproductive health 8 (2), 164–179.

HERNÁNDEZ-ÁVILA, J.E; RODRÍGUEZ, M.-H; SANTOS-LUNA, R; SÁNCHEZ-CASTAÑEDA, V; ROMÁN-PÉREZ, S; RÍOS-SALGADO, V.H. & SALAS-SARMIENTO, J.A. (2013): Nation-wide, web-based, geographic information system for the integrated surveillance and control of dengue fever in Mexico. In: PloS one 8 (8), e70231.

HICKS, L.L. (1990): Availability and accessibility of rural health care. In: J Rural Health 6 (4), 485–505.

HILHORST, D. & LEEUWEN, M. van (2000): Emergency and Development: the Case of Imidugudu, Villagization in Rwanda. In: Journal of Refugee Studies 13 (3), 264–280.

HINTJENS, H.M. (1999): Explaining the 1994 Genocide in Rwanda. In: The Journal of Modern African Studies 37 (2), 241–286.

HUERTA MUNOZ, U. & KÄLLESTÅL, C. (2012): Geographical accessibility and spatial coverage modeling of the primary health care network in the Western Province of Rwanda. In: International journal of health geographics 11, 40.

HUFF, D.L. (1963): Determination of Intra-Urban Retail Trade Areas. Real Estate Research Program, Graduate School of Business Administration.

HUFF, D.L. (1964): Defining and Estimating a Trading Area. In: Journal of Marketing 28 (3), 34–38.

HUFF, D.L. (2000): Don't misuse the Huff model in GIS. In: Business Geographies 8 (8), 12.

HUFF, D.L. (2003): Parameter Estimation in the Huff Model. In: ArcUser, ESRI (October-December), 34–36. — Online: http://www.esri.com/news/arcuser/1003/files/huff.pdf (accessed: 2013-11-29).

HUFF, D. & MCCALLUM, B.M. (2008): Calibrating the Huff Model Using ArcGIS Business Analyst. An ESRI White Paper. — Online: http://www.esri.com/library/whitepapers/pdfs/calibrating-huff-model.pdf (accessed: 2014-11-18).

HUYE DISTRICT (2007): Huye District Development Plan. — Online: http://www.huye.gov.rw/uploads/media/DDP_2008-2013.pdf (accessed: 2014-02-22, URL updated).

HUYE DISTRICT (2011): Mutuelle de Santé registration data, Huye District, 2010. Received from Rissa Antoinette Ntakirutimana on 2011-04-06. Butare, Rwanda.

IMHOF, E. (1950): Gelände und Karte. Zürich: Rentsch.

ISAKSSON, A.-S. (2011): Manipulating the rural landscape: Villagisation and income generation in Rwanda June 2011. — Online: https://gupea.ub.gu.se/bitstream/2077/25865/1/gupea_2077_25865_1.pdf (accessed: 2013-10-21).

JOSEPH, A.E. & Phillips, D.R. (1984): Accessibility and Utilization: Geographical Perspectives on Health Care Delivery. London: Harper and Row.

KALK, A; MAYINDO, J.K; MUSANGO, L. & FOULON, G. (2005): Paying for health in two Rwandan provinces: financial flows and flaws. In: Tropical Medicine & International Health 10 (9), 872–878.

KEARNS, R.A. & Gesler, W.M. (1998): Putting health into place: Landscape, identity, and well-being: Syracuse University Press.

KEARNS, R. & MOON, G. (2002): From medical to health geography: novelty, place and theory after a decade of change. In: Progress in Human Geography 26 (5), 605–625.

KHAN, A.A. (1992): An Integrated Approach to Measuring Potential Spatial Access to Health Care Services. In: Socio-Economic Planning Sciences 26 275–287.

KHAN, A.A. & BHARDWAJ, S.M. (1994): Access to health care. A conceptual framework and its relevance to health care planning. In: Evaluation & the health professions 17 (1), 60–76.

KINZER, S. (2008): A thousand hills. Rwanda's rebirth and the man who dreamed it. Hoboken, N.J.: John Wiley & Sons.

KISTEMANN, T; DANGENDORF, F. & SCHWEIKART, J. (2002): New perspectives on the use of Geographical Information Systems (GIS) in environmental health sciences. In: International Journal of Hygiene and Environmental Health 205 (3), 169–181.

KISTEMANN, T; LEISCH, H. & SCHWEIKART, J. (1997): Geomedizin und Medizinische Geographie. Entwicklung und Perspektiven einer "old partnership". In: Geographische Rundschau (4), 198–203.

KISTEMANN, T. & SCHWEIKART, J. (2010): Geographische Gesundheitsforschung: Von der Krankheitsökologie zur Geographie der Gesundheit. In: Geographische Rundschau (7-8), 4–10.

KIWANUKA, S.N; EKIRAPA, E.K; PETERSON, S; OKUI, O; RAHMAN, M.H; PETERS, D. & PARIYO, G.W. (2008): Access to and utilisation of health services for the poor in Uganda: a systematic review of available evidence. In: Trans R Soc Trop Med Hyg 102 (11), 1067-1074.

KNOX, P.L. (1978): The intraurban ecology of primary medical care: patterns of accessibility and their policy implications. In: Environment and Planning A 10 (4), 415–435.

KOHLER, J; NGABO, F; MAKAKA, A; SWITLICK-PROSE, K. & HATT, L. (2012): The “Insurance Effect”: Exploring Health Insurance and Family Planning Uptake in Rwanda .

KUMAR, K. & Millwood, D. (1996): Rebuilding Postwar Rwanda. The Role of the International Community. The International Response to Conflict and Genocide: Lessons learnt from the Rwanda Experience Study 4. Odense, Denmark: Steering Committee of the Joint Evaluation of Emergency Assistance to Rwanda.

KYOMUHENDO, G.B. (2003): Low use of rural maternity services in Uganda: impact of women's status, traditional beliefs and limited resources. In: Reprod Health Matters 11 (21), 16–26.

LANGMUIR, E. (1984): Mountain craft and Leadership. Leicester: The Scottish Sport Council/MLTB.

LEWANDO HUNDT, G; ALZAROO, S; HASNA, F. & ALSMEIRAN, M. (2012): The provision of accessible, acceptable health care in rural remote areas and the right to health: Bedouin in the North East region of Jordan. In: Social science & medicine (1982) 74 (1), 36–43.

LEWIS, C. (1977): Improved access through regionalization. In: GINZBURG, E. (Ed.), Regionalization and health policy. U.S. Department of Health, Education and Welfare Publication No. HRA 77-623. Washington, DC: U.S. Government Printing Office, 71–84.

LIU, J.J. (2007): Health professional shortage and health status and health care access. In: J Health Care Poor Underserved 18 (3), 590–598.

LOGIE, D.E; ROWSON, M. & NDAGIJE, F. (2008): Innovations in Rwanda's health system: looking to the future. In: Lancet 372 (9634), 256–261.

LOUIS RUSA; MIRIAM SCHNEIDMAN; GYURI FRITSCHE & LAURENT MUSANGO Rwanda (2009): Performance-Based Financing in the Public Sector. In: RENA EICHLER, RUTH LEVINE & THE PERFORMANCE-BASED INCENTIVES WORKING GROUP (Eds.), Performance incentives for global health potential and pitfalls. Baltimore: BROOKINGS INSTITUTION PRESS, 189–214.

LUO, J. (2014): Integrating the Huff Model and Floating Catchment Area Methods to Analyze Spatial Access to Healthcare Services. In: Transactions in GIS 18 (3), 436–448.

LUO, W. & QI, Y. (2009): An enhanced two-step floating catchment area (E2SFCA) method for measuring spatial accessibility to primary care physicians. In: Health Place 15 (4), 1100–1107.

LUO, W. & WANG, F. (2003): Measures of spatial accessibility to health care in a GIS environment: synthesis and a case study in the Chicago region. In: Environment and Planning B: Planning and Design 30 (6), 865–884.

LUO, W. & WHIPPO, T. (2012): Variable catchment sizes for the two-step floating catchment area (2SFCA) method. In: Infectious Insecurities 18 (4), 789–795.

MACKIAN, S; BEDRI, N. & LOVEL, H. (2004): Up the garden path and over the edge: where might health-seeking behaviour take us? In: Health policy and planning 19 (3), 137–146.

MAMDANI, M. & BANGSER, M. (2004): Poor People's Experiences of Health Services in Tanzania: A Literature Review. In: Reproductive Health Matters 12 (24), 138–153.

MARTIN, C; CURTIS, B; FRASER, C. & SHARP, B. (2002): The use of a GIS-based malaria information system for malaria research and control in South Africa. In: South African Perspectives on Geography of Health 8 (4), 227–236.

MARTIN, D; RODERICK, P; DIAMOND, I; CLEMENTS, S. & STONE, N. (1998): Geographical aspects of the uptake of renal replacement therapy in England. In: International Journal of Population Geography 4 (3), 227–242.

MAY, J.M. (1950): Medical Geography: Its Methods and Objectives. In: Geographical Review 40 (1), 9–41.

MAY, J.M. (1977): Medical geography: Its methods and objectives. In: Social Science & Medicine 11 (14–16), 715–730.

MAYER, J.D. (1982): Relations between Two Traditions of Medical Geography: Health Systems Planning and Geographical Epidemiology. In: Progress in Human Geography 6 (2), 216–230.

MAYER, J.D. (1990): The centrality of medical geography to human geography: the traditions of geographical and medical geographical thought. In: Norsk Geografisk Tidsskrift - Norwegian Journal of Geography 44 (4), 175–187.

MCGRAIL, M.R. (2012): Spatial accessibility of primary health care utilising the two step floating catchment area method: an assessment of recent improvements. In: International journal of health geographics 11, 50.

MCGRAIL, M.R. & HUMPHREYS, J.S. (2009): A new index of access to primary care services in rural areas. In: Aust N Z J Public Health 33 (5), 418–423.

MCGUIRK, M.A. & PORELL, F.W. (1984): Spatial patterns of hospital utilization: the impact of distance and time. In: Inquiry a journal of medical care organization, provision and financing 21 (1), 84–95.

MEADE, M.S. & Earickson, R.J. (2000[2]): Medical geography. New York: Guilford Press.

MEADE, M.S. & Emch, M. (2010[3]): Medical geography. New York: Guilford Press.

MECHANIC, D. (1972): Public expectations and health care: Essays on the changing organization of health services. New York: Wiley-Interscience.

MEESSEN, B; MUSANGO, L; KASHALA, J.-P.I. & LEMLIN, J. (2006): Reviewing institutions of rural health centres: the Performance Initiative in Butare, Rwanda. In: Tropical Medicine & International Health 11 (8), 1303–1317.

MELVERN, L. (2000): A people betrayed. The role of the West in Rwanda's genocide. New York, N.Y.: Zed Books.

MENNIS, J. (2003): Generating Surface Models of Population Using Dasymetric Mapping. In: The Professional Geographer 55 (1), 31–42.

MINISTRY OF EDUCATION (MINEDUC)[RWANDA](2013): 2012 Education Statistics Yearbook. — Online:http://www.mineduc.gov.rw/IMG/pdf/2012_Education_statistical_yearbook.pdf (access: 2013-10-18).

MINISTRY OF FINANCE AND ECONOMIC PLANNING (MINECOFIN)[RWANDA](2000): Vision 2020. – Online: http://www.gesci.org/assets/files/Rwanda_Vision_2020.pdf (accessed: 2015-04-19).

MINISTRY OF FINANCE AND ECONOMIC PLANNING (MINICOFIN)[RWANDA](2007): Economic Development and poverty Reduction Strategy 2008-2012. Draft 090707 . — Online: http://www.rada.gov.rw/IMG/pdf/EDPRS_Version_July_9th.pdf (accessed: 2011-04-15).

MINISTRY OF FINANCE AND ECONOMIC PLANNING (MINECOFIN)[RWANDA](2012): Economic Development and Poverty Reduction Strategy 2013 – 2018. Shaping our development. — Online: http://www.minecofin.gov.rw/fileadmin/General/EDPRS_2/EDPRS_2_FINAL1.pdf (accessed: 2014-09-01).

MINISTRY OF HEALTH (MOH)[RWANDA](2009): Health Sector Strategic Plan. July 2009 - June 2012. — Online http://transition.usaid.gov/rw/our_work/for_partners/images/rwandahealthsector-strategicplanii.pdf (accessed: 2013-03-01).

MINISTRY OF HEALTH (MOH)[RWANDA](2010a): Annual Report. July 2009 - June 2010. — Online: http://www.moh.gov.rw/fileadmin/templates/MOH-Reports/Final-MoH-annual-report-July-2009-June-2010.pdf (accessed: 2015-04-07).

MINISTRY OF HEALTH (MOH)[RWANDA](2010b): Health Facilities in Rwanda. Personal Geodatabase downloaded on 2010-03-28 (not accessible anymore).

MINISTRY OF HEALTH (MOH)[RWANDA](2010c): Health Facilities in Rwanda. Updated data received from Randy Wilson, MSH on 2010-09-15. Kigali, Rwanda.

MINISTRY OF HEALTH (MOH)[RWANDA](2010d): Utilization by zone per health center for 2008. Health Management Information System (HMIS). Received from Emilien Nkusi (Coordinator) on 2010-02-03. Kigali, Rwanda.

MINISTRY OF HEALTH (MOH)[RWANDA](2011): Utilization by zone per health center, Huye District, 2010. Health Management Information System (HMIS). Received from Emilien Nkusi (Coordinator) on 2011-08-29. Kigali, Rwanda.

MINISTRY OF HEALTH (MOH)[RWANDA](2012): Rwanda Annual Health Statistics Booklet 2012. — Online: http://www.moh.gov.rw/fileadmin/templates/MOH-Reports/MOH_Booklet_2012_final_September_2013.pdf (accessed: 2014-09-08).

MINISTRY OF HEALTH (MOH)[RWANDA](2013): Rwanda HRH Program - Health System . — Online: http://hrhconsortium.moh.gov.rw/rwanda-at-a-glance/ (accessed: 2013-01-14).

MINISTRY OF HEALTH OF RWANDA (MOH); NATIONAL INSTITUTE OF STATISTICS OF RWANDA & ICF MACRO (2009): Interim Demographic and Health Survey 2007-08. — Online: http://rochr.qrc.com/bitstream/123456789/339/1/FR215.pdf (accessed: 2011-07-10).

MINISTRY OF INFRASTRUCTURE (MININFRA)[RWANDA](2012): Public transport policy and strategy for Rwanda. — Online: http://www.mininfra.gov.rw/fileadmin/templates/Laws_Regulation_Transport_sector/Public_Transport_Policy_and_Strategy_for_Rwanda.pdf (accessed: 2013-10-20).

MINISTRY OF LOCAL GOVERNMENT (MINALOC)[RWANDA](2014): Progress made and main achievements registered from 2009 to 2013. — Online: http://www.minaloc.gov.rw/fileadmin/documents/Minaloc_Documents/PROGRESS_MADE_AND_MAIN_ACHIEVEMENTS_REGISTERED_FROM_2009_TO_2013_RSTF.pdf (assessed: 2015-04-13).

MINISTRY OF YOUTH AND ICT (MYICT)[RWANDA](2012): Rwanda ICT Sector Profile – 2012. — Online: http://admin.theiguides.org/Media/Documents/Rwanda-ICT-Profile-2012.pdf (accessed: 2014-09-05).

MOBLEY, L.R; ROOT, E; ANSELIN, L; LOZANO-GRACIA, N. & KOSCHINSKY, J. (2006): Spatial analysis of elderly access to primary care services. In: Int J Health Geogr 5, 19.

MOON, G. (2009): Health Geography. In: KITCHIN, R. & THRIFT, N. (Eds.), International Encyclopedia of Human Geography. Oxford: Elsevier, 35–45.

MOONEY, G.H. (1983): Equity in health care: confronting the confusion. In: Effective health care 1 (4), 179–185.

MUNCH, Z; VAN LILL, S.W.P; BOOYSEN, C.N; ZIETSMAN, H.L; ENARSON, D.A. & BEYERS, N. (2003): Tuberculosis transmission patterns in a high-incidence area: a spatial analysis. In: The International Journal of Tuberculosis and Lung Disease 7 (3), 271–277.

MURAWSKI, L. & CHURCH, R.L. (2009): Improving accessibility to rural health services: The maximal covering network improvement problem. In: Socio-Economic Planning Sciences 43 (2), 102–110.

MUSAFIRI, E. (2012): Building peace in post-genocide Rwanda. Prospects and challenges. Saarbrücken: LAP LAMBERT Academic Publishing.

NAISMITH, W. (1892): Notes and Stories. Cruach Ardran, Stobinian, and Ben More. In: Scottish Mountaineering Club Journal II (3), 135–136.

NATIONAL INSTITUTE OF STATISTICS OF RWANDA (NISR)(2006): Preliminary Poverty Update Report. Integrated living conditions survey 2005/2006. — Online: http://statistics.gov.rw/sites/default/files/user_uploads/files/survey-reports/Master%20Report%20Poverty%20Update.pdf (accessed: 2013-10-18).

NATIONAL INSTITUTE OF STATISTICS OF RWANDA (NISR)(2012a): 2012 Population and Household Census. Provisional Results. — Online: http://www.statistics.gov.rw/sites/default/files/user_uploads/files/books/2012_POPULATION_HOUSING_CENSUS_latest.pdf (accessed: 2013-10-16).

NATIONAL INSTITUTE OF STATISTICS OF RWANDA (NISR)(2012b): 2012 Population and Housing Census: village data. Received from Florent Bigirimana, NISR, GIS Unit on 2012-11-15. Kigali, Rwanda.

NATIONAL INSTITUTE OF STATISTICS OF RWANDA (NISR)(2012c): Roads data set. Received from Florent Bigirimana, GIS Unit on 2012-11-15. Kigali, Rwanda.

NATIONAL INSTITUTE OF STATISTICS OF RWANDA (NISR)(2013): Stastical Year Book 2012. — Online: http://statistics.gov.rw/system/files/user_uploads/files/books/YEAR%20BOOK_2012.pdf (accessed: 2015-04-06).

NATIONAL INSTITUTE OF STATISTICS OF RWANDA (NISR)(2014): Rwanda's Mobile phone penetration rised over past five years. — Online: http://www.statistics.gov.rw/publications/article/rwanda%E2%80%99s-mobile-phone-penetration-rised-over-past-five-years (accessed: 2014-06-27).

NATIONAL INSTITUTE OF STATISTICS OF RWANDA (NISR)(2015): Fourth Population and Housing Census, Rwanda, 2012. District Profile Huye. — Online: http://statistics.gov.rw/sites/default/files/user_uploads/files/books/Huye_District_profiles.pdf (accessed: 2015-04-04).

NATIONAL INSTITUTE OF STATISTICS OF RWANDA (NISR) & MINISTRY OF FINANCE AND ECONOMICS PLANNING (MINECOFIN)[RWANDA](2012a): EICV3 District Profile. South - Huye. — Online: http://statistics.gov.rw/system/files/user_uploads/files/books/HUYE.pdf (accessed: 2015-03-06)

NATIONAL INSTITUTE OF STATISTICS OF RWANDA (NISR) & MINISTRY OF FINANCE AND ECONOMIC PLANNING (MINECOFIN)[RWANDA](2012b): Fourth Population and Housing Census, Rwanda, 2012. Thematic Report: Population Size, Structure and Distribution. — Online: http://statistics.gov.rw/publications/rphc4-thematic-report-population-size-structure-and-distribution (accessed: 2014-06-02).

NATIONAL INSTITUTE OF STATISTICS OF RWANDA (NISR) & MINISTRY OF FINANCE AND ECONOMICS PLANNING (MINECOFIN)[RWANDA](2012c): Rwanda - Enquête Intégrale sur les conditions de vie des ménages 2010-2011. — Online: http://microdata.statistics.gov.rw/index.php/catalog/36/get_microdata (accessed: 2015-03-05).

NATIONAL INSTITUTE OF STATISTICS OF RWANDA (NISR); MINISTRY OF HEALTH (MOH)[RWANDA] & ICF INTERNATIONAL (2012): Rwanda Demographic and Health Survey 2010 . — Online: http://www.statistics.gov.rw/publications/demographic-and-health-survey-2010-final-report (accessed: 2012-05-21).

NATIONAL INSTITUTE FOR STATISTICS RWANDA (NISR); MINISTRY OF HEALTH (MOH)[RWANDA] & MACRO INTERNATIONAL (2008): Service Provision Assessment Survey 2007. — Online: http://rochr.qrc.com/bitstream/123456789/2175/1/SPA15.pdf (accessed: 2011-07-10 ; not accessible anymore).

NATIONAL INSTITUTE OF STATISTICS OF RWANDA (NISR) & MINISTRY OF FINANCE AND ECONOMIC PLANNING (MINECOFIN)[RWANDA](2006): Demographic and Health Survey 2005. — Online: http://dhsprogram.com/pubs/pdf/FR183/FR183.pdf (accessed: 2015-04-19).

NATIONAL LAND CENTER (NLC)[RWANDA](2008a): Aerial photographs for Mbazi and Ruhashya Sector, 25 x 25 cm resolution. Received from Jean Marie Kuradusenge, GIS Department, 2010-09-21. Kigali, Rwanda.

NATIONAL LAND CENTER (NLC)[RWANDA](2008b): Orthophoto, Huye District, 2 x 2 m resolution. Received from Jean Marie Kuradusenge, GIS Department, 2010-09-21. Kigali, Rwanda.

NATIONAL LAND CENTER (NLC)[RWANDA](2010): List of Imidugudu. Received from Jean Marie Kuradusenge, GIS Department, 2010-09-21. Kigali, Rwanda.

NATIONAL LAND CENTER (NLC)[RWANDA](2011): Geodata. Received from Jean Marie Kuradusenge, GIS Department, 2011-04-19. Kigali, Rwanda.

NOOR, A.M; ALEGANA, V.A; GETHING, P.W. & SNOW, R.W. (2009): A spatial national health facility database for public health sector planning in Kenya in 2008. In: International Journal of Health Geographics 8 (13).

NOOR, A.M; AMIN, A.A; GETHING, P.W; ATKINSON, P.M; HAY, S.I. & SNOW, R.W. (2006): Modelling distances travelled to government health services in Kenya. In: Trop Med Int Health 11 (2), 188–196.

NOOR, A.M; GIKANDI, P.W; HAY, S.I; MUGA, R.O. & SNOW, R.W. (2004): Creating spatially defined databases for equitable health service planning in low-income countries: the example of Kenya. In: Acta Trop 91 (3), 239–251.

NOOR, A.M; ZUROVAC, D; HAY, S.I; OCHOLA, S.A. & SNOW, R.W. (2003): Defining equity in physical access to clinical services using geographical information systems as part of malaria planning and monitoring in Kenya. In: Tropical Medicine and International Health 8 (10), 917–926.

NYKIFORUK, C.I.J. & FLAMAN, L.M. (2011): Geographic Information Systems (GIS) for Health Promotion and Public Health: A Review. In: Health Promotion Practice 12 (1), 63–73.

OBRIST, B; ITEBA, N; LENGELER, C; MAKEMBA, A; MSHANA, C; NATHAN, R; ALBA, S; DILLIP, A; HETZEL, M.W; MAYUMANA, I; SCHULZE, A. & MSHINDA, H. (2007): Access to health care in contexts of livelihood insecurity: a framework for analysis and action. In: PLoS medicine 4 (10), 1584–1588.

OGUNYEMI, S; MUIBI, K; EGUAROJE, O; FABIYI, O. & HALILU, A. (2014): A geospatial approach to evaluation of accessibility to secondary educational institution in Ogun State, Nigeria. In: IOP Conference Series: Earth and Environmental Science 20 (1), 12045.

OPPONG, J.R. (2008): Rwanda. Modern world nations. New York: Chelsea House Publishers.

OPPONG, J.R. & HODGSON, M.J. (1994): Spatial Accessibility to Health Care Facilities in Suhum District, Ghana. In: The Professional Geographer 46 (2), 199–209.

PANDE, S; KEYZER, M.A; AROUNA, A. & SONNEVELD, B.G. (2008): Addressing diarrhea prevalence in the West African Middle Belt: social and geographic dimensions in a case study for Benin. In: Int J Health Geogr 7 17.

PARKER, E.B. & CAMPBELL, J.L. (1998): Measuring access to primary medical care: some examples of the use of geographical information systems. In: Health & Place 4 (2), 183–193.

PARKHURST, J.O; RAHMAN, S.A. & SSENGOOBA, F. (2006): Overcoming access barriers for facility-based delivery in low-income settings: insights from Bangladesh and Uganda. In: J Health Popul Nutr 24 (4), 438–445.

PARKHURST, J.O. & SSENGOOBA, F. (2009): Assessing access barriers to maternal health care: measuring bypassing to identify health centre needs in rural Uganda. In: Health Policy Plan 24 (5), 377–384.

PAUL, F. (2009): Health Worker Motivation and the Role of Performance Based Finance Systems in Africa. A Qualitative Study on the Rwandan Performance Based Finance Initiative in Hospitals. Master Thesis. Development Studies Institute. London School of Economics and Political Science.

PENCHANSKY, R. & THOMAS, J.W. (1981): The concept of access: definition and relationship to consumer satisfaction. In: Med Care 19 (2), 127–140.

PERRY, B. & GESLER, W. (2000): Physical access to primary health care in Andean Bolivia. In: Soc Sci Med 50 (9), 1177–1188.

PETERS, D.H; GARG, A; BLOOM, G; WALKER, D.G; BRIEGER, W.R. & RAHMAN, M.H. (2008): Poverty and access to health care in developing countries. In: Annals of the New York Academy of Sciences 1136 161–171.

PHILO, C. (2009[5]): medical geography. In: GREGORY, D., JOHNSTON, R., PRATT, G., WATTS, M.J. & WHATMORE, S. (Eds.), The dictionary of human geography. Malden, MA: Blackwell, 451–453.

RAHMAN, A; KRAKAUER, N; ROYTMAN, L; GOLDBERG, M. & KOGAN, F. (2010): Application of advanced very high resolution radiometer (AVHRR)-based vegetation health indices for estimation of malaria cases. In: The American journal of tropical medicine and hygiene 82 (6), 1004–1009.

RAY, N. & EBENER, S. (2008): AccessMod 3.0: computing geographic coverage and accessibility to health care services using anisotropic movement of patients. In: International journal of health geographics 7 63.

RAY, N., Santiago, H; Colombo, R. & Ebener, S. (2012): AccessMod 4.0 Extension to ArcGIS 9.3.1. User's Manual (2014-06-24) . — Online: http://www.arcgis.com/home/item.html?id=f64ccd70c3e045eb8ba6811033c9def6 (accessed: 2015-03-24).

REES, W.G. (2003): Naismith's rule overhauled .

REES, W.G. (2004): Least-cost paths in mountainous terrain. In: Computers & Geosciences 30 (3), 203–209.

REYNTJENS, F. (1997): Estimation du nombre de personnes tuées au Rwanda en 1994. In: MARYSSE, S. & REYNTJENS, F. (Eds.), L'Afrique des Grands Lacs - Annuaire 1996-1997. Paris: L'Harmattan, 179–186.

RIFKIN, S.B. & WALT, G. (1986): Why health improves: Defining the issues concerning 'comprehensive primary health care' and 'selective primary health care'. In: Social Science & Medicine 23 (6), 559–566.

RISHER, K; ADAMS, D; SITHOLE, B; KETENDE, S; KENNEDY, C; MNISI, Z; MABUSA, X. & BARAL, S.D. (2013): Sexual stigma and discrimination as barriers to seeking appropriate healthcare among men who have sex with men in Swaziland. In: Journal of the International AIDS Society 16 (3 Suppl 2), 18715.

RODRIGUEZ POSE, R. & SAMUELS, F. (2011): Rwanda's Story: Progress on health in Rwanda: Leadership, performance and health insurance. — Online: http://www.developmentprogress.org/sites/developmentprogress.org/files/rwanda_health_progress.pdf (accessed: 2013-03-15).

ROSEN, L. ET AL. (1975): Development of accessibility indexes for ambulatory care providers. Report prepared for the Office of Planning, Evaluation and Legislation. Health Services Administration.

ROSENBERG, M.W. (1998): Medical or health geography? Populations, peoples and places. In: International journal of population geography 4 (3), 211–226.

RUGUMIRE, P. (2013): New information system increasing access to health data in Rwanda. MSH, 2013-09-20. — Online: https://www.msh.org/news-events/stories/new-information-system-increasing-access-to-health-data-in-rwanda (accessed: 2015-03-24).

RUTHERFORD, M.E; MULHOLLAND, K. & HILL, P.C. (2010): How access to health care relates to under-five mortality in sub-Saharan Africa: systematic review. In: Tropical Medicine & International Health 15 (5), 508–519.

SAKSENA, P; ANTUNES, A.F; XU, K; MUSANGO, L. & CARRIN, G. (2010): Impact of mutual health insurance on access to health care and financial risk protection in Rwanda. World Health Report (2010) Background Paper, 6. — Online: http://www.who.int/healthsystems/topics/financing/healthreport/RwandaNo6FINAL.pdf (accessed: 2013-03-14).

SAKSENA, P; ANTUNES, A.F; XU, K; MUSANGO, L. & CARRIN, G. (2011): Mutual health insurance in Rwanda: Evidence on access to care and financial risk protection. In: Health Policy 99 (3), 203–209.

SALKEVER, D.S. (1975): Economic class and differential access to care: comparisons among health care systems. In: International Journal of Health Services 5 (3), 373–395.

SCHMIDT, J.-O; MAYINDO, J.K. & KALK, A. (2006): Thresholds for health insurance in Rwanda: who should pay how much? In: Tropical Medicine & International Health 11 (8), 1327–1333.

SCHNEIDER, P. & DIOP, F. (2004): Community-Based Health Insurance in Rwanda. Chapter 7. In: PREKER, A.S. & CARRIN, G. (Eds.), Health Financing for Poor People: Resource Mobilization and Risk Sharing. Washington, DC, Geneva: World Bank; Worlh Health Organization; International Labour Office, 251–274.

SCHNEIDER, P. & HANSON, K. (2006): Horizontal equity in utilisation of care and fairness of health financing: a comparison of micro-health insurance and user fees in Rwanda. In: Health Economics 15 (1), 19–31.

SCHUR, N; HÜRLIMANN, E; GARBA, A; TRAORÉ, M.S; NDIR, O; RATARD, R.C; TCHUEM TCHUENTÉ, L.-A; KRISTENSEN, T.K; UTZINGER, J. & VOUNATSOU, P. (2011): Geostatistical model-based estimates of Schistosomiasis prevalence among individuals aged ≤ 20 years in West Africa. In: PLoS neglected tropical diseases 5 (6), e1194.

SCHUURMAN, N; BÉRUBÉ, M. & CROOKS, V.A. (2010): Measuring potential spatial access to primary health care physicians using a modified gravity model. In: Canadian Geographer / Le Géographe canadien 54 (1), 29–45.

SCHUURMAN, N; FIEDLER, R.S; GRZYBOWSKI, S.C. & GRUND, D. (2006): Defining rational hospital catchments for non-urban areas based on travel-time. In: Int J Health Geogr 3 (5).

SCHWEIKART, J. (1992): Räumliche und soziale Faktoren bei der Annahme von Impfungen in der Nord-West Provinz Kameruns. In: BARSCH, D., FRICKE, W. & MEUSBURGER, P. (Eds.), Heidelberger Geographische Schriften 92. Heidelberg: Selbstverlag des Geographischen Instituts der Universität Heidelberg.

SCHWEIKART, J. (2007): Auf dem Weg zu einer besseren Gesundheit - welchen Beitrag kann der Einsatz von Geoinformationssystemen liefern? In: STROBL, J. & BLASCHKE, T. (Eds.), Angewandte Geoinformatik 2007: Beiträge zum 19. AGIT-Symposium Salzburg. Heidelberg: Wichmann, 731–735.

SEKABARAGA, C; DIOP, F. & SOUCAT, A. (2011): Can innovative health financing policies increase access to MDG-related services? Evidence from Rwanda. In: Health policy and planning 26 (suppl 2), ii52.

SELLSTRÖM, T., Wohlgemuth, L. & Millwood, D. (1996): Historical perspective. Some explanatory factors. The International Response to Conflict and Genocide: Lessons learnt from the Rwanda Experience Study 1. Odense, Denmark: Steering Committee of the Joint Evaluation of Emergency Assistance to Rwanda.

SHAIKH, B.T. & HATCHER, J. (2005): Health seeking behaviour and health service utilization in Pakistan: challenging the policy makers. In: J Public Health (Oxf) 27 (1), 49–54.

SHANNON, G.W; SKINNER, J.L. & BASHSHUR, R.L. (1973): Time and distance: the journey for medical care. In: International Journal of Health Services 3 (2), 237–244.

SHAW, N.T. (2012): Geographical Information Systems and Health: Current State and Future Directions. In: Healthcare Informatics Research 18 (2), 88.

SHYAKA MUGABE, A.M. & Tuyisabe, F. (2007): Community conflicts in Rwanda: Major causes and ways to solutions. Republic of Rwanda, National Unity and Reconciliation Commission (NURC). December 2007. Kigali, Rwanda. — Online: http://www.nurc.gov.rw/fileadmin/templates/nurc/css/Community_conflict_in_Rwanda.pdf (accessed: 2015-04-19).

SIMOONGA, C; UTZINGER, J; BROOKER, S; VOUNATSOU, P; APPLETON, C.C; STENSGAARD, A.S; OLSEN, A. & KRISTENSEN, T.K. (2009): Remote sensing, geographical information system and spatial analysis for schistosomiasis epidemiology and ecology in Africa. In: Parasitology 136 (13), 1683–1693.

SITHIPRASASNA, R; LEE, W.J; UGSANG, D.M. & LINTHICUM, K.J. (2005): Identification and characterization of larval and adult anopheline mosquito habitats in the Republic of Korea: potential use of remotely sensed data to estimate mosquito distributions. In: International journal of health geographics 4 17.

SLEETER, R. & GOULD, M. (2007): Geographic Information System Software to Remodel Population Data Using Dasymetric Mapping Methods. — Online: http://pubs.usgs.gov/tm/tm11c2/tm11c2.pdf (accessed: 2015-01-30).

SLIFKIN, R.T. (2002): Developing policies responsive to barriers to health care among rural residents: what do we need to know? In: J Rural Health 18 Suppl 233–241.

SOCIALIST WORKER (2004): Genocide in Rwanda. — Online: http://socialistworker.org/2004-1/498/498_08_Rwanda.shtml (accessed: 2014-09-04).

SOUZA GOMES, E.C. de; LEAL-NETO, O.B; ALBUQUERQUE, J; PEREIRA DA SILVA, H. & BARBOSA, C.S. (2012): Schistosomiasis transmission and environmental change: a spatio-temporal analysis in Porto de Galinhas, Pernambuco, Brazil. In: International journal of health geographics 11, 51.

STRASSER, R. (2003): Rural health around the world: challenges and solutions. In: Family Practice 20 (4), 457–463.

STRONG, M; MAHESWARAN, R; PEARSON, T. & FRYERS, P. (2007): A method for modelling GP practice level deprivation scores using GIS. In: Int J Health Geogr 6, 38.

SUDHOF, L; AMOROSO, C; BAREBWANUWE, P; MUNYANEZA, F; KARAMAGA, A; ZAMBOTTI, G; DROBAC, P. & HIRSCHHORN, L.R. (2013): Local use of geographic information systems to improve data utilisation and health services: mapping caesarean section coverage in rural Rwanda. In: Tropical medicine & international health 18 (1), 18–26.

TAKEUCHI, S. & MARARA, J. (2000): Agriculture and Peasants in Rwanda: A Preliminary Report. Institute of Developing Economies, Japan External Trade Organization. — Online: http://www.ide.go.jp/English/Publish/Download/Jrp/127.html (accessed: 2015-04-19).

TANSER, F. (2006): Geographical Information Systems (GIS) Innovations For Primary Health Care in Developing Countries. In: Innovations - Technology, Governance, Globalization spring, 106.

TANSER, F; GIJSBERTSEN, B. & HERBST, K. (2006): Modelling and understanding primary health care accessibility and utilization in rural South Africa: an exploration using a geographical information system. In: Soc Sci Med 63 (3), 691–705.

TANSER, F; HOSEGOOD, V; BENZLER, J. & SOLARSH, G. (2001): New approaches to spatially analyse primary health care usage patterns in rural South Africa. In: Tropical Medicine & International Health 6 (10), 826–838.

TEY, N.-P. & LAI, S.-l. (2013): Correlates of and barriers to the utilization of health services for delivery in South Asia and Sub-Saharan Africa. In: The Scientific World Journal 2013, Article ID 423403, 11 p.

THE WORLD BANK (2001): African Development Indicators 2001. — Online: https://openknowledge.worldbank.org/handle/10986/13925 (accessed: 2014-09-08).

THE WORLD BANK (2005): African Development Indicators 2005. From the World Bank Africa Database. Washington: World Bank Publications.

THE WORLD BANK (2013a): Literacy rate, adult total (% of people ages 15 and above) . — Online: http://data.worldbank.org/indicator/SE.ADT.LITR.ZS/countries/RW-ZF-XM?display=default (accessed: 2013-10-18).

THE WORLD BANK (2013b): Rwanda Economic Update, May 2013. Maintaining Momentum with a Special Focus on Rwanda's Pathway Out of Poverty. — Online: https://openknowledge.worldbank.org/handle/10986/16564 (accessed: 2014-06-24).

THE WORLD BANK (2015): Population density. — Online: http://data.worldbank.org/indicator/EN.POP.DNST?order=wbapi_data_value_2013+wbapi_data_value+wbapi_data_value-last&sort=desc (accessed: 2015-04-13).

THOMSON, M.C; CONNOR, S.J; MILLIGAN, P. & FLASSE, S.P. (1997): Mapping malaria risk in Africa. What can satellite data contribute? In: Parasitology Today 13 (8), 313–318.

TOBLER, W. (1993): Three presentations on geographical analysis and modeling. National Center for Geographic Information and Analysis. Technical Report 93-1.

TRAN, A; PONÇON, N; TOTY, C; LINARD, C; GUIS, H; FERRÉ, J.-B; LO SEEN, D; ROGER, F; LA ROCQUE, S. de; FONTENILLE, D. & BALDET, T. (2008): Using remote sensing to map larval and adult populations of

Anopheles hyrcanus (Diptera: Culicidae) a potential malaria vector in Southern France. In: International journal of health geographics 7, 9.

TSOKA, J.M. & LE SUEUR, D. (2004): Using GIS to measure geographical accessibility to primary health care in rural South Africa. Research in action. In: South African Journal of Science 100 (7 & 8), 329.

TWIGG, L. (1990): Health based geographical information systems: Their potential examined in the light of existing data sources. In: Special Issue Medical Geography - Recent Case Studies and Concerns 30 (1), 143–155.

UEBERSCHÄR, N. & IYIKIRENGA, L. (2009): Entwicklung eines geographischen Ansatzes zur Malaria-Überwachung in Ruanda. In: STROBL, J. (Ed.), Angewandte Geoinformatik 2009: Beiträge zum 21. AGIT-Symposium Salzburg. Heidelberg: Wichmann, 315–321.

UNITED NATIONS (2006): Investment Policy Review Rwanda. New York & Geneva: United Nations Conference on Trade and Development. — Online: http://unctad.org/en/docs/iteipc200611_en.pdf (accessed: 2014-09-08).

UNITED NATIONS DEVELOPMENT PROGRAMME (UNDP)(2010): Human Development Report 2010. The Real Wealth of Nations: Pathways to Human Development. — Online: http://hdr.undp.org/en/media/HDR_2010_EN_Complete_reprint.pdf (accessed: 2013-01-15).

UNITED NATIONS DEVELOPMENT PROGRAMME (UNDP)(2012a): About Rwanda. — Online: http://www.rw.undp.org/content/rwanda/en/home/countryinfo/ (accessed: 2015-04-10).

UNITED NATIONS DEVELOPMENT PROGRAMME (UNDP)(2012b): HDI Indicators by Country 2012. — Online: https://data.undp.org/dataset/HDI-Indicators-by-Country-2012/nz26-sffk? (accessed: 2014-06-27).

UNITED NATIONS DEVELOPMENT PROGRAMME (UNDP)(2012c): Reduce Child mortality. Where we are. — Online: http://www.rw.undp.org/content/rwanda/en/home/mdgoverview/overview/mdg4/ (accessed: 2015-04-10).

UNITED NATIONS HEADQUARTERS (2008a): Millennium Development Goal 1: Eradicate extreme poverty and hunger. Fact Sheet. — Online: http://www.un.org/millenniumgoals/2008highlevel/pdf/newsroom/Goal%201%20FINAL.pdf (accessed: 2015-04-10).

UNITED NATIONS HEADQUARTERS (2008b): Millennium Development Goal 4: Reduce child mortality. Fact Sheet. — Online: http://www.un.org/millenniumgoals/2008highlevel/pdf/newsroom/Goal%204%20FINAL.pdf (accessed: 2015-04-10).

UNITED NATIONS HEADQUARTERS (2008c): Millennium Development Goal 5: Improve maternal health. Fact Sheet. — Online: http://www.un.org/millenniumgoals/2008highlevel/pdf/newsroom/Goal%205%20FINAL.pdf (accessed: 2015-04-10).

UNITED NATIONS HEADQUARTERS (2008d): Millennium Development Goal 6: Combat HIV/AIDS, malaria and other diseases. Fact Sheet. — Online: http://www.un.org/millenniumgoals/2008highlevel/pdf/newsroom/Goal%206%20FINAL.pdf (accessed: 2015-04-10).

VALENČIUS, C.B. (2000): Histories of medical geography. In: Medical history. Supplement (20), 3–28.

VAN DER HOEVEN, M; KRUGER, A. & GREEFF, M. (2012): Differences in health care seeking behaviour between rural and urban communities in South Africa. In: International Journal for Equity in Health 11 (1), 31.

WAKABI, W. (2007): Rwanda makes health-facility deliveries more feasible. In: Lancet 370 (9595), 1300.

WAN, N; ZOU, B. & STERNBERG, T. (2012): A three-step floating catchment area method for analyzing spatial access to health services. In: International Journal of Geographical Information Science 26 (6), 1073–1089.

WANG, F. & LUO, W. (2005): Assessing spatial and nonspatial factors for healthcare access: towards an integrated approach to defining health professional shortage areas. In: Health & Place 11 (2), 131–146.

WILLIAMS, L.D. (2014): Understanding the relationships among HIV/AIDS-related stigma, health service utilization, and HIV prevalence and incidence in Sub-Saharan Africa: a multi-level theoretical perspective. In: American journal of community psychology 53 (1-2), 146–158.

WORLD HEALTH ORGANIZATION (WHO)(1978): Declaration of Alma-Ata (2008-05-02) . — Online: http://www.who.int/publications/almaata_declaration_en.pdf (accessed: 2013-07-31).

WORLD HEALTH ORGANIZATION (WHO)(2006): The World Health Report 2006 - working together for health. – Online: http://www.who.int/whr/2006/en/ (accessed: 2015-04-19).

YANG, D.-H; GOERGE, R. & MULLNER, R. (2006): Comparing GIS-based methods of measuring spatial accessibility to health services. In: Journal of medical systems 30 (1), 23–32.

YESHIWONDIM, A.K; GOPAL, S; HAILEMARIAM, A.T; DENGELA, D.O. & PATEL, H.P. (2009): Spatial analysis of malaria incidence at the village level in areas with unstable transmission in Ethiopia. In: International Journal of Health Geographics (8), 5.

ZWARENSTEIN, M; KRIGE, D. & WOLFF, B. (1991): The use of a geographical information system for hospital catchment area research in Natal/KwaZulu. In: S Afr Med J 80 (10), 497–500.

Interview partners

NKUSI, EMILIEN (2009): COORDINATOR HEALTH MANAGEMENT INFORMATION SYSTEM, MINISTRY OF HEALTH RWANDA, PERSONAL CONVERSATION. KIGALI, RWANDA: 2009-11-11.

FISCHER, ANJA (2010): GTZ Rwanda, personal conversation. Kigali, Rwanda: 2010-09-13.

NTAKIRUTIMANA, RISSA ANTOINETTE (2011): Mutuelle de Santé Huye District, personal conversation. Butare, Rwanda: 2011-04-06.

KARENGERA, STEPHEN (2009): Director of Policy Planning and Capacity Building Unit, Ministry of Health Rwanda, personal conversation. Kigali, Rwanda: 2009-11-09.

UWIZEYE, PETRONILLE (2011): Head of Huye District Health Unit, personal conversation. Gitarama, Rwanda: 2011-08-31.

WILSON, RANDY (2011): Management Sciences for Health in cooperation with MoH Rwanda, Senior HMIS and Data Use Advisor, Integrated Health System Strengthening Project, personal conversation. Kigali, Rwanda: 2011-08-01.

Health Centers:

ANITA (2011): Nurse at Health Center Rubona, personal conversation at the health center, 2011-03-25.

ANIZIA (2010): Nurse at Health Center Matyazo, personal conversation at the health center, 2010-09-25.

CESAIRE (2011): Nurse at Health Center Rango, personal conversation at the health center, 2011-08-31.

CLAUDINE (2010): Nurse at Health Center Rango, personal conversation at the health center, 2010-09-25.

DESIRE (2010): Titulaire at Health Center Rango, personal conversation at the health center, 2010-09-25.

EUDÈTE (2010): Titulaire at Health Center Mbazi, personal conversation at the health center, 2010-09-24.

FELICIEN (2010): Titulaire at Health Center Rwaniro, personal conversation at the health center, 2010-09-24.

FELICITÉ (2010): Nurse at Health Center CUSP, personal conversation at the health center, 2010-09-25.

FELIX (2010): Titulaire at Health Center Busoro-Gishamvu, personal conversation at the health center, 2010-09-24.

FRANCINE (2010): Titulaire at Health Center Rubona, personal conversation at the health center, 2010-09-24.

INNOCENT (2010): Titulaire at Health Center Ruhashya, personal conversation at the health center, 2010-09-24.

JAPHET (2011): Nurse at Health Center Buroso-Gishamvu, personal conversation at the health center, 2011-08-31.

LAURENCE (2010): Nurse at Health Center Rusatira, personal conversation at the health center, 2010-09-25.

LIBERATA (2010): Nurse at Health Center Sovu, personal conversation at the health center, 2010-09-25.

MOSES (2010): Titulaire at Health Center Police, personal conversation at the health center, 2010-09-25.

ROSE (2010): Nurse at Health Center Kinyamakara, personal conversation at the health center, 2010-09-24.

SR. ATANASIE (2011): Nurse at Health Center Matyazo, personal conversation at the health center, 2011-08-31.

SR. EURILIA (2010): Nurse at Health Center Simbi, personal conversation at the health center, 2010-09-24.

SR. JOLANDA (2010): Titulaire Health Center Karama, personal conversation at the health center, 2010-09-25.

Small group discussion, Butare, Rwanda:

MUHARUGO, ALICE (2013): Nutritionist at Health Center Matyazo. 2013-12-09.

NGIRIMANA, DIEUDONNE (2013): Titulaire at Health Center Mbazi. 2013-12-09.

NSABUMUREMYI, JANVIER (2013): Nutritionist at Health Center Huye Police. 2013-12-09.

Appendix I: Study protocol as submitted and approved by the Ethics Committee in the Ministry of Health

Revised Study Protocol to the
Rwanda National Ethics Committee

Spatial disparities in the utilisation of health facilities in Huye District (Rwanda)

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Contents

Synopsis

Numerous problems pointed out in Rwanda's Vision 2020, the Economic Development and poverty Reduction Strategy (EDPRS) and several Millennium Development Goals are related (beyond other factors) to the access to health care. In this study the main objective is to analyse this access to health care under the spatial point of view. By collecting data in health centres about the origin of patients as well as their major means of transport, the costs, the time spent to reach the health centre and reasons for seeking care in a certain health centre, a model for the estimation of catchment areas will be defined with help of a geographic information system. Doing so, I hope to contribute to a more equitable contribution of resources for health care.

1 Background

“Public health and health care are important concerns for developing countries and access to health care is a significant factor that contributes to a healthy population” (Black et al. 2004). The geographical situation including place of residence and location of healthcare services are important factors in the analysis of the health status of the population. Spatial access to medical treatment, as part of the millennium development goals to reduce the burden of HIV/AIDS, tuberculosis and malaria (United Nations Headquarters 2008a, 2008b, 2008c), is a critical factor in effective health treatment for people in rural areas of developing countries (Murawski & Church 2009; McGrail et al. 2009; Hall et al. 2008).

To reveal existing barriers to the use of health services, including distance, transportation, informal costs or low perceived quality, has been the objective of several studies (Parkhurst & Ssengooba 2009; Noor et al. 2006; Noor et al. 2009; Pristas et al. 2009; Goudge et al. 2009; Logie et al. 2008). But also person related barriers as age, sex, ethnicity, income or insurance status have been found to be reasons for disparities in access to health care (Graves 2008). The impact of different barriers on the utilisation of health facilities is still under investigation. Parkhurst and Ssengooba (2009) as well as Akin and Hutchinson (1999) for example found patients by-passing the nearest health facility in order to reach a more popular one.

In this context geographical information systems (GIS) are an emerging technology in the analysis of health. GIS can integrate health data with mapping functions which allows the visualization, exploration and modelling of health patterns. Application of GIS technology has been proofed to be helpful for various aspects of health care access and health outcomes (Graves 2008; Noor et al. 2009; Basara & Yuan 2008; Guagliardo 2004).

2 Aim and objectives

I aim to determine factors which influence patients' decision-making process in the usage of a certain health facility; then describe, analyse and explain them concerning their spatial effects. The main objective of this doctoral study is to improve the process of estimating health facility catchment areas in rural Rwanda by developing a model with help of GIS. I aim to combine most important factors of the decision making process with spatial effects with those factors given by the configuration of the area to an optimised modelling process for catchment areas.

The objectives of the survey are:

- To determine the actual catchment area of selected health centres.
- To collect information about the means of transport mainly used by patients to reach the health centre.
- To determine reasons for the visit of a certain health centre.
- To develop a model for the catchment areas.
- To review the transferability of the model to the catchment areas of health centres in other districts.

As requested by the WHO, catchment areas are also in Rwanda calculated with a 5 km Euclidean distance or one hour travel time (by foot). I believe that an improved calculation of catchment areas will lead to more justice in the assignment of funding, as already started with the performance based funding strategy, and the ability of better planning for the distribution of drugs, staff, services and equipment. The results can contribute to the plans of the Ministry of Health to improve the geographical access to health care (MoH 2009).

3 Methods

3.1 Study description

Numerous problems pointed out in Rwanda's Vision 2020, the Economic Development and poverty Reduction Strategy (EDPRS) and the Millennium Development Goals (MDGs) 4, 5 and 6 concerning the reduction of child mortality, maternal mortality and HIV/AIDS, malaria and other diseases, are related (beyond other factors) to the access to health care (see e.g. MINECOFIN 2002; MINECOFIN 2007; United Nations Headquarters 2008a; United Nations Headquarters 2008b; United Nations Headquarters 2008c). Penchansky & Thomas (1981) have defined five dimensions of access: accommodation, affordability, acceptability, availability, accessibility. All of them influence the utilisation of health facilities. The availability as well as the accessibility are dependent on the location of the health facility, which can be determined with help of a GIS. The other three dimensions are mainly dependent on each patient (financial situation, education, family background, gender issues, religious beliefs or cultural traditions and taboos) or the health facility itself (e.g. equipment, staff, supply of water or electricity, offer of services).

Because I assume that patients are not always seeking for health care at the closest health facility, as also Parkhurst and Ssengooba (2009) as well as Akin and Hutchinson (1999) pointed out in their studies, the visit of a certain health facility is of interest in this study. Also data provided by the Ministry of Health of Rwanda shows that up to 70 % of the patients are not coming from the assigned catchment area.

To be able to define different factors for the estimation of catchment areas a mixed method approach is used. Primary data collection with patients at health centres in August/September 2010 will lead to answers about the means of transport, their costs, the patient's background as well as reasons for the utilisation of a certain health facility.

Secondary data regarding the origin of patients will be taken into account, too. Data available in the Health Management Information System (HMIS) for 2008 that is aggregating the origin of patients in "from the zone", "from other zones" and "from other districts" will be used. Additionally forms which are filled by patients at health centres before receiving treatment will be recorded to cross check with other data and to reach a higher number of patients' origin data. Data from the Performance Based Funding Programme and from the Demography and Health Surveys carried out in Rwanda will be considered for the analysis of the data. Also access to data from the Clinton Foundation about health facilities is expected.

After analysing the data, a model for catchment areas will be developed with help of GIS. The results will be discussed in the district and at health facilities to include the experience of health related staff. In a second step the developed model for the calculation will be tested for other districts.

3.2 Study design

3.2.1 Survey at health centres

Based on different requirements (see section 3.3) the health centres in Huye District have been selected from the database of the Ministry of Health (as at March 2010) for this survey. Interviewers (in couples) will stay for one day at each selected health centre and will interview every patient who comes to the health centre based on a questionnaire (see Appendix A).

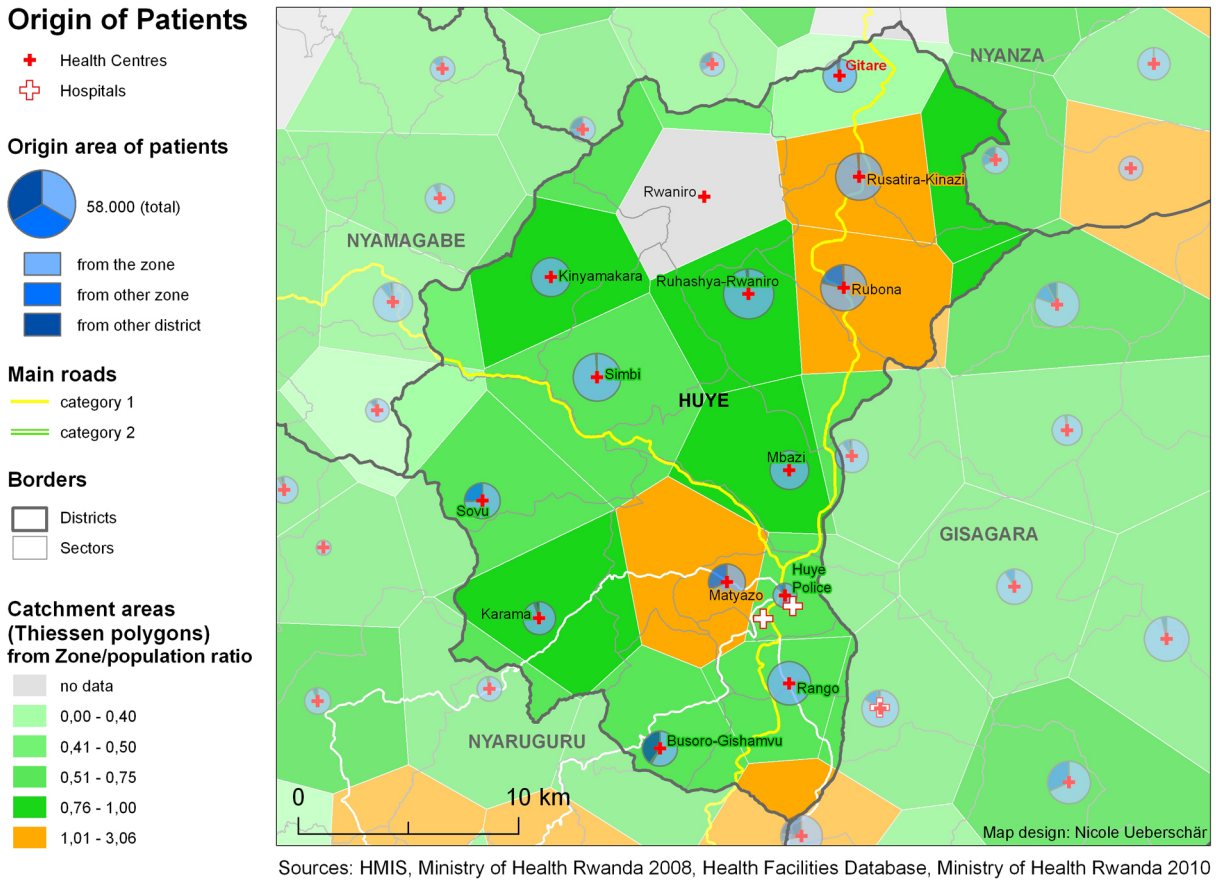
3.2.2 Other data

Available data from the HMIS for 2008 has been used to get a first overview of the utilisation of health centres (see Figure 1). It will furthermore be used to reveal either a development from 2008 to 2010 or if the data is found to be still valid it will be used for the model that will lead to the calculation of catchment areas.

Forms which are filled by patients at health centres before receiving treatment will be copied digitally to record them afterwards. The data for March and July 2010 will be copied to take into account a rainy and a dry season. This data will only be recorded by myself to remain the best confidentiality of the data. Only relevant data will be recorded, including the date of consultation, as most detailed as possible the origin of the patient, the name, which will only be used to see if the patient was coming back, the sex and the age. This data will also be used for comparisons with other data but mainly to get a higher number of patients' origin data than possible by the survey.

3.3 Selection of study area

Data regarding the origin of patients is available in the Health Management Information System (HMIS) in an aggregated way. The data for 2008 has been included into the GIS and used for the selection (referred to as HMIS2008 in the following). The Ministry of Health mentioned interest in the survey including also an urban area to analyse its influence on the utilisation of surrounding health centres. This was also taken into account by choosing the district of Huye for this survey. To improve the transferability of the developed model for catchment areas a district was chosen which contains an urban area and which has some outliers like Busoro-Gishamvu with only about 60 % or Kinyamakara with almost 100 % of patients coming from the assumed catchment area. Also the fact that for three health centres a higher number of patients than the population which is estimated to be served is reported makes this district interesting for the survey (HMIS2008, see Figure 1). Including the wish to use available resources and considering restricted available funding this district seemed to be the best option to meet all requirements.



Sources: HMIS, Ministry of Health Rwanda 2008, Health Facilities Database, Ministry of Health Rwanda 2010

Figure 1: Selected district for survey. Data is not correct in all points: Gitare Health Centre (placed in the north of Huye District) is in the database assigned to the Burera District; the health centre CUSP Butare is placed in the Nyanza District although it should be assigned to Huye.

3.4 Study population

Interviewers in couples will ask every patient who is coming to the health centre at a certain day (see schedule Table 3) if he or she wants to participate in the survey. If possible, the questionnaire (see Appendix A) will be filled together with the patient during the waiting time. Interviewers will be at the health centre the whole day (depending on opening hours) to reach patients who come from close as well as patients who need more time to reach the health centre.

Data recorded at health centres will take into account all patients seeking for health care in the months of March and July 2010.

4 Study procedures

4.1 Procedures at enrolment

After the patient arrived at the health centre and was registered for treatment the interviewer will inform him/her briefly about the survey (see introducing text on questionnaires, Appendix A) and will ask him/her to participate. If the patient expects to be waiting for at least 20 minutes to be treated at the health centre he/she will be asked to do the interview based on the questionnaire (see Appendix A) immediately in a separate room or in a silent place in or at the health centre. At the beginning of all interviews, participants will be informed of the purpose and nature of the study and its expected benefits. Participants will be made aware that, giving their consent by signature or thumb print, they agree to participate in the survey (see Appendix B). If the patient does not want to do the interview before his/her consultation/treatment he/she is asked to come to the place/room for the interview afterwards. The needed time for the interview is estimated with 20 minutes including the information and the consent of the patient.

4.2 Measurement of exposures and confounders

4.2.1 Survey at health centres

Risks for the survey at health centres are a low frequency at a health centre at the scheduled day of the survey and low response rates. If the number of filled questionnaires does not reach 20, interviewers will come back the next day or a day in the following week. This might be especially the case with weather conditions which don't allow travelling long distances by foot. This risk should be reduced by conducting the survey during the dry season. The survey schedule cannot consider dependencies of utilisation on certain days of the week. Recorded data of March and July 2010 will give information about the correlation of the days of a week with number of consultations and the patients' origin.

4.2.2 Recording of available data

For the recording of available data at health centres the consent of the Health Officer at each health centre in Huye District is assumed. Missing data at certain health centres can reduce the number of samples. Data from 2008 (HMIS2008) will be used as benchmark.

4.3 Measurement of outcomes

To each health centre the patients' origins will be assigned. The patients will be aggregated in age groups per village, cell and sector, respectively. Data will be

analysed regarding possible correlations of travelled distances, means of transport, costs of transport, reason for consultation as well as health facility related factors.
Indicators for the measurement of outcomes are defined as (see questionnaire Appendix A):

a) Next available health centre (questions 4 and 11): From the origin of the patient the next available health centre based on road network and in Euclidean distance is calculated.
b) Reported distance/estimated distance ratio (questions 4 and 16): The ratio of the reported distance to the estimated distance based on reported origin and road network.
c) Costs per travelled distance (questions 14 to 16): Reported costs in relation to reported distance and estimated distance based on the roads network.
d) Means of transport by travelled distance (questions 13 and 16): The reported means of transport in relation to the reported distance and estimated distance based on the roads network.
e) Utilisation of health services dependent on the education status (questions 9, 10, 19, 22, 23, 24).
f) Ranking of decision influencing factors (question 26).

4.4 Sample size

4.4.1 Survey at health centres

In September 2008, about 24,000 new cases have been registered at those health centres which are assigned to Huye district (14 health centres) with data missing for Rango and Rwaniro for this month. Considering the data of 2008 for the scheduled time of the survey (September 1 until 9, 2010) at each health centre 35 up to more than 100 patients per day can be expected. The two interviewers will interview as many patients as possible. With an estimated time of 20 minutes per questionnaire and two interviewers, about six questionnaires can be filled per hour. Depending on opening hours of health centres approximately 40 to 60 patients could be interviewed per health centre. Considering less frequently visited health centres the total is estimated with 500 filled questionnaires assuming a high response rate.

Table 1: Utilisation of health facilities in August and September 2008, Huye District (Source: Ministry of Health, HMIS2008)

Code	PBFCode	Name	Aug. male	Aug. female	Sept. male	Sept. female	Average per day
520101	649	Busoro-Gishamvu	-	-	723	704	95
520201	650	Sovu	672	1035	694	898	80
520301	651	Karama	518	747	575	727	60
520401	652	Kinyamakara	1005	990	1020	1039	100
520701	654	Mbazi	684	1236	648	1130	90
520901	655	CUSP Butare	733	1067	734	1167	91
520902	835	Matyazo	658	994	622	903	77
520903	914	Huye Police	330	565	298	448	35
521001	656	Ruhashya-Rwaniro	1374	1628	1341	1391	47
521101	653	Rubona	968	1385	939	1412	139
521102	700	Rusatira-Kinazi	1058	1580	1062	1519	115
521301	657	Simbi	1078	1610	1119	1864	127
521401	658	Rango	961	1494	-	-	142
	915	Rwaniro	-	-	-	-	-
		Huye (total)	10952	14520	10699	13466	

- no data

4.4.2 Recording of available data

For recording of available data at health centres about 25,000 records are estimated to be copied digitally for March 2010 and again about 25,000 for July 2010. Those numbers would represent the values of 2008.

4.5 Data Management

Data from questionnaires will be entered twice by two different persons into a database with reference to the corresponding questionnaire for cross- and back checking. Digitally copied patient information sheets will be entered into a database by the researcher. The names of the patients will be coded and not stored in the same database. Data will be stored and analysed with SPSS and Microsoft Excel. Spatial analysis will be done with ESRI® ArcMap™.

4.6 Proposed analysis

4.6.1 Survey at health centres

Demographic data

Data will be analysed regarding sex, age and origin of patients. This data can be validated with data from previous months (secondary data at health centres for March and July 2010) and will show how representative the survey has been regarding the demographic structure of patients. Origin data will be analysed regarding the distance to the next available health centre based on road network. Data about the financial situation will be analysed regarding the family structure and regarding the affordability of health services, considering the expenses needed to seek for health care (see questionnaire questions 1 to 10, Appendix A).

Data regarding utilisation of health facilities

Questions 11 to 17 are related to the spatial accessibility of the health centre as well as the affordability regarding costs of transport. Costs will be analysed in relation to the travelled distance and the means of transport. Also the used means of transport will be put in relation to the travelled distance. I aim to find patterns in the used means of transport related to the travelled distance, combined with the cost and the time needed to reach the health centre.

Question 18 will be analysed regarding the frequency of different health insurance systems. With question 19 I want to investigate if the patient knows of other health centres or other possibilities for seeking primary health care.

Question 20 is aiming to find mobility reducing factors which can influence the ability to travel long distances and which will have an influence on the travel time needed.

Question 21 will be analysed in categories of illness if there are correlations between illness and travelled distance.

Question 22 will give information about the importance of seeing a traditional healer before seeking for health care at a health centre.

Questions 23 and 24 will give information about the frequency and the utilisation of different health centres. The consultation of different health centres because of the same illness can give an idea of satisfaction of patients with a health facility.

Questions 25 and 26 are mainly related to the health centre and will give information about the acceptability and the importance of this acceptability for the decision making process.

4.6.2 Recorded patient information sheets

Data will be analysed regarding sex, age and origin of patients. It will be used for validation of utilisation data from the survey and will be cross checked with data from

HMIS2008. Additionally patients' origin data will be analysed for inclusion into the model of catchment area calculation.

5 Ethical considerations

5.1 Confidentiality

All data will be treated confidentially. The participants will not be asked for their names. The students who will carry out the interviews with the patients will sign an obligation of confidentiality (see Appendix C).

5.2 Informed consent

The interviewer will conduct the informed consent process directly with patients. The interviewer will ensure that only those participants who agree to consent are enrolled in the study. All potential respondents will be made aware at the outset that their participation is voluntary and does not affect their eligibility to receive services at present or in the future. At the start of all interviews, participants will be informed orally of the purpose and nature of the study, and its expected benefits. Participants will be made aware that, giving their consent by signature or thumb print, they agree to participate in the survey.

The consent text and the survey questionnaire will be read and written in Kinyarwanda or English, depending on the preferred language of the patient (see Appendix A and B).

As part of the consent procedure, the participant will be informed that the data collected will be held in strict confidence.

The respondent will be made aware at the outset that he or she is free to terminate the interview at any point, and to skip any question that he/she does not wish to respond to, or to withdraw from the study, without penalty. Lastly, the participant will be allowed to ask questions before deciding to participate (see introducing text of questionnaire, Appendix A).

5.3 Ethical approval

The magnitude of harm or discomfort anticipated in the present research is expected to be low. Some survey questions may cause emotional distress in respondents, such as those associated with the financial situation of the family or the reason of the visit at the health centre. However, interviewers will receive special training on how to respond to situations when participants become uncomfortable. If any respondent appears very uncomfortable through body language, the interviewer will be trained to ask the participant if he or she wants to skip the question or to stop the interview, respectively.

To protect the confidentiality of the given information, all interviewers will receive strict instructions about the importance of maintaining confidentiality and will have

signed agreements to maintain confidentiality (see Appendix C). Identifying information will not be recorded on the completed questionnaire.
All interviews will be conducted in a safe, private place in or around the health centre where other patients are unable to hear.
Filled questionnaires will not be saved with any linkage to the patient. Thus, also the final database for analysis will contain no subject names. Particular care will be taken during the presentation of the research findings that the information presented is sufficiently aggregated to ensure that no individual is identifiable.

Copied patient information sheets

Data will be stored digitally in locked closets where only the researcher has access to. Recorded data will be stored in two different files containing the name and a referral number in one file and the other data (sex, age, origin and the referral number) in a separate file. The files will be stored on two different devices and in two different locked closets. Only the researcher will know about the linkage of the files. For further analysis only the number of visits at the health centre per patient will be used but no names. The digital copies will be deleted after the analysis.

6 Logistics

6.1 Distribution of responsibilities

The applicant is responsible for the selection of health centres. Students are hired as interviewers, who will be trained in interviewing the patients. To each health centre a couple of one male and one female interviewer will be assigned. The interviewers will be responsible for each interview. The applicant will supervise interviews in the pre-test phase and single interviews during the survey.
Secondary data will be copied and recorded by the applicant herself.

6.2 Timetable

Table 2: Overview of the doctoral project (2010)

2010	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Phase 1 - basics												
Literature review												
Data review												
GIS visualization												
Phase 2 - patients survey												
Pre-test of question-naire and improve-ments if needed												
Interviews with patients at health centres												
Collecting/Retrieving secondary data from health centres												
Processing of interview data												
Recording of secondary data												
GIS analysis (ongoing in 2011)												

Table 3: Fieldwork schedule – Survey at health centres
(based on map in Figure 1, excluding HC Gitare, CUSP Butare added; subject to modifications)

Aug. 30 – Sept. 3, 2010	**Mon**	**Tue**	**Wed**	**Thu**	**Fri**
Matyazo					
Karama					
Rango					
Busoro-Gishamvu					
Mbazi					
Sovu					

Sept. 6 – Sept. 10, 2010	**Mon**	**Tue**	**Wed**	**Thu**	**Fri**
Huye Police					
CUSP Butare					
Rwaniro					
Ruhashya-Rwaniro					
Rusatira-Kinazi					
Rubona					
Simbi					
Kinyamakara					
reserved as alternative date					

scheduled date for health centre alternative date

6.3 Budget

The research will not be funded by any institution and will only be covered by the researcher herself. Therefore the budget for per-diems and a car/driver will be set as low as possible. Estimates are outlined in Table 4.

Table 4: Estimated budget for fieldwork

	price per day (US$)	**total amount per day (US$)**	**number of days**	**total (US$)**
car and driver	125	125	11	1375
per-diem per interviewer (x4)	20	80	7	560
total				**1935**

7 References

Akin, J. S. & Hutchinson, P. (1999). Health-care facility choice and the phenomenon of bypassing. *Health Policy Plan, 14*(2), 135-151.

Basara, H. G. & Yuan, M. (2008). Community health assessment using self-organizing maps and geographic information systems. *Int J Health Geogr, 7*, 67.

Black, M., Ebener, S., Aguilar, P. N., Vidaurre, M. & Morjani, Z. E. (2004). Using GIS to Measure Physical Accessibility to Health Care. WHO.

Goudge, J., Gilson, L., Russell, S., Gumede, T. & Mills, A. (2009). Affordability, availability and acceptability barriers to health care for the chronically ill: longitudinal case studies from South Africa. *BMC Health Serv Res, 9*, 75.

Graves, B. A. (2008). Integrative literature review: a review of literature related to geographical information systems, healthcare access, and health outcomes. *Perspect Health Inf Manag, 5*, 11.

Guagliardo, M. F. (2004). Spatial accessibility of primary care: concepts, methods and challenges. *Int J Health Geogr 3*, 3

Hall, A. G., Lemak, C. H., Steingraber, H. & Schaffer, S. (2008). Expanding the definition of access: it isn't just about health insurance. *J Health Care Poor Underserved, 19*(2), 625-638.

Logie, D. E., Rowson, M. & Ndagije, F. (2008). Innovations in Rwanda's health system: looking to the future. *Lancet, 372*(9634), 256-261.

McGrail, M. R. & Humphreys, J. S. (2009). A new index of access to primary care services in rural areas. *Aust N Z J Public Health, 33*(5), 418-423.

MINECOFIN (2002). *Vision 2020*. Draft 3, English Version, Kigali, November 2002, Republic of Rwanda, Ministry of Finance and Economic Planning. — online: http://www.cdf.gov.rw/documents%20library/important%20docs/Vision_2020.pdf.

MINECOFIN (2007). *Economic Development and poverty Reduction Strategy 2008-2012*. Draft 090707, Republic of Rwanda, Ministry of Finance and Economic Planning. — online: http://www.rada.gov.rw/IMG/pdf/EDPRS_Version_July_9th.pdf.

MoH (2009). *Annual Report 2008*. Rebublic of Rwanda, Ministry of Health. — online: http://www.moh.gov.rw/index.php?option=com_docman&task=doc_download&gid=116&Itemid=13.

Murawski, L. & Church, R. L. (2009). Improving accessibility to rural health services: The maximal covering network improvement problem. *Socio-Economic Planning Sciences, 43*(2), 102-110.

Noor, A. M., Alegana, V. A., Gething, P. W. & Snow, R. W. (2009). A spatial national health facility database for public health sector planning in Kenya in 2008. *International Journal of Health Geographics, 8*(13).

Noor, A. M., Amin, A. A., Gething, P. W., Atkinson, P. M., Hay, S. I. & Snow, R. W. (2006). Modelling distances travelled to government health services in Kenya. *Trop Med Int Health, 11*(2), 188-196.

Parkhurst, J. O. & Ssengooba, F. (2009). Assessing access barriers to maternal health care: measuring bypassing to identify health centre needs in rural Uganda. *Health Policy Plan, 24*(5), 377-384.

Penchansky, R. & Thomas, J. W. (1981). The concept of access: definition and relationship to consumer satisfaction. *Med Care, 19*(2), 127-140.

Pristas, I., Bilic, M., Voncina, L., Krcmar, N., Polasek, O. & Stevanovic, R. (2009). Health care needs, utilisation and barriers in Croatia – regional and urban-rural differences. *Coll Antropol, 33 Suppl 1*, 121-130.

United Nations Headquarters (2008a). Millennium Development Goal 4: Reduce child mortality, Fact Sheet. New York, 25 September 2008. — online: http://www.un.org/millenniumgoals/2008highlevel/pdf/newsroom/Goal%204%20FINAL.pdf.

United Nations Headquarters (2008b). Millennium Development Goal 5: Improve maternal health, Fact Sheet. New York, 25 September 2008. — online: http://www.un.org/millenniumgoals/2008highlevel/pdf/newsroom/Goal%205%20FINAL.pdf.

United Nations Headquarters (2008c). Millennium Development Goal 6: Combat HIV/AIDS, malaria and other diseases, Fact Sheet. New York, 25 September 2008. — online: http://www.un.org/millenniumgoals/2008highlevel/pdf/newsroom/Goal%206%20FINAL.pdf.

Appendix A: Questionnaire for survey at health centres

(see following pages)

First some questions to your person.

Bimwe mu bibazo ku mwirondoro wawe

1. Sex / *igitsina*: ☐ female / *Gore* ☐ male / *Gabo*

2. Age / *imyaka y'amavuko*: _____ years / *imyaka*

3. Are you visiting this health centre today for yourself or are you accompanying another patient? / *Waba waje gusura iki kigo nderabuzima cyangwa hari uwo waherekeje?*

   ☐ I am the patient. / *Ndi umurwayi.*

   ☐ I am accompanying my child / *Mperekeje umwana.*
   Age of the child/*Imyaka y'umwana*: _____

   ☐ I am accompanying a friend's/relative's child / *Mperekeje inshuti yanjye/umwana dufitanye isano.*
   Age of the child/*Imyaka y'umwana*: _____

   ☐ I am accompanying a friend/a relative / *Mperekeje inshuti/umuntu dufitanye isano.*

   ☐ else / *undi* _____

4. Origin / *aho uturuka*: Umudugudu _____ Cell / *Akagari* _____
   Sector / *Umurenge* _____ District / *Akarere* _____

5. How many people live in your household? */ Ni abantu bangahe baba iwawe murugo?* _____
   How many children under 15 years? / *Harimo abana bangahe bari munsi y'imyaka 15?* _____
   How many children do you have? / *Ufite abana bangahe?* _____
   How many of your children live in your household? / *Mu bana bawe usigaranye na bangahe?* _____

6. What is your profession?/ *Umuriga wawe?*

   ☐ Farmer*/Umuhinzi*
   ☐ Trader*/Umucuruzi*
   ☐ Public worker*/Umukozi wa leta*
   ☐ Private sector, NGO, project*/Umukozi w'ikigo/umushinga kigenga*
   ☐ Student */ Umunyeshuri*
   ☐ Other/*Uwundi*: _____

7. Did you attend school? /*Waba warize?* ☐ yes/*Yego* ☐ no/*Oya*

   If yes /*Niba ari yego*

   ☐ I attended some years primary school./ *Nacikije amashuri abanza.*
   ☐ I finished primary school./ *Narangije amashuri abanza.*
   ☐ I attended some years secondary school./ *Nacikije amashuri yisumbuye.*
   ☐ I finished secondary school./ *Narangije amashuri yisumbuye.*
   ☐ I am a student at an university (or compareable)./ *Ndi umunyeshuri muri kamnuza.*
   ☐ I studied for some years at a university (or compareable)./ *Nacikije kaminuza.*
   ☐ I finished university./ *Narangije kaminuza.*

8. Please read the following sentence. Please read loudly. / *Washobora iyi nteruro. Soma cyane.*

   [Interviewer: Show one of the text samples to the patient and mark afterwards!]

   ☐ yes/*Yego* ☐ no/*Oya*

In this section we would like to get information about your visit to this health centre today.
Muri iki gice dukeneye amakuru yerekeranye no kuza hano kwawe kuri iki kigonderabuzima uyu mumsi?

9. Where did you come from? / *Waturutse he?*
   - ☐ from home / *Mu rugo*
   - ☐ from work / *Ku kazi*
   - ☐ from a relative / *Ku muntu wo mu muryango*
   - ☐ else / *undi* _____

10. How did you come here? / *Mwageze hano gute?*
    - ☐ by foot / *N'amaguru*
    - ☐ by taxi (bus) / *Na tagisi (bisi)*
    - ☐ by moto taxi / *N'ipikipiki (tagisi)*
    - ☐ else / *ukundi* _____

11. Can you use the same path to come here during the rainy season? /
    Ushobora gukoresha inzira wajemo mu gihe cy'imvura.

    ☐ yes/*Yego* ☐ no/*Oya* ☐ do not know / *Simbizi*

12. How many km is it from your home to this hc? (appr.) _____ km
    Kuva murugo rwawe kugera ku kigonderabuzima hari km zinganhe? Ikigereranyo.

13. How much did it cost you to come here (one way)? /
    Byagutwaye amafaranga angahe kugera hano atagize ahandi hantu unyuze? _____ RWF

14. How much time did it take you to come here (one way)? / _____ minutes / *Iminota*
    Byagutwaye igihe kingana iki kugera hano nta handi unyuze?

    walking time _____ minutes / *Iminota*
    igihe cy'urugendo rw'amaguru?

    time for waiting for public transport _____ minutes / *Iminota*
    igihe cyo gutegereza ikinyabiziga rusange?

    time for travelling in public transport _____ minutes / *Iminota*
    igihe cy'urugendo rw'ikinyabiziga?

    else/ *ibindi* _____ minutes / *Iminota*

15. Which of the following statements are applicable to you? (multiple answers possible)
    Ni iyihe muri izi nteruro zikurikira ubona ari zo (ushobora gutanga ibisubizo byinshi)

    - ☐ I have fever. / *Mfite umuriro.*
    - ☐ I am pregnant. / *Ndatwite.*
    - ☐ I have a broken leg. / *Navunitse akaguru.*
    - ☐ To walk is difficult for me. / *Ntago ngenda neza.*
    - ☐ I cannot see well. / *Ntago mbona neza.*
    - ☐ I need help for walking. / *Nkenera ubufasha kugirango mbashe kugenda.*
    - ☐ I have severe pain. / *Mfite ububabare bwinshi.*
    - ☐ I feel weak. / *Mfite integer nke.*

16. Did you stop on your way coming here? / *Wigeze uhagarara mu nzira uje hano?* ☐ yes/*Yego* ☐ no/*Oya*

    If yes: Where/Why did you stop? / *Niba iri yego, wahagaze he? Kubera iki wahagaze?*

    _____

    _____

17. To which health insurance system do you belong to?/*Ukoresha ubuhe bwisungane mu buvuzi?*

    ☐ Mutuelle
    ☐ RAMA
    ☐ MMI
    ☐ FARG
    ☐ Other/*Ubundi:* _____
    ☐ do not belong to any health insurance system/*Nta na bumwe.*

18. What is the reason of your visit?/*Ni iyihe mpamvu nyamukuru yakuzanye?*

    ☐ acute symptoms, urgent help needed / *ibimenyetso bishya, ubufasha bwihutirwa*
    ☐ regular treatment/*imiti usanzwe ufata*
    ☐ else/*ibindi* _____
    ☐ I do not want to answer./*Sinshaka gusubiz.*

19. Which ways do you know for seeking primary health care? (What kind? Where? Name?)
    Ni ubuhe buryo uzi burifashishwa mu kwivuza (Ubuhe bwoko? Hehe? Izina?)

    1. _____ / _____ / _____
    2. _____ / _____ / _____
    3. _____ / _____ / _____
    4. _____ / _____ / _____
    5. _____ / _____ / _____

20. Did you see a traditional healer because of this same illness?
    Waba warivuje iyi ndwara mu kinyarwanda/ku muvuzi wa gihanga?

    ☐ yes/*Yego* ☐ no/*Oya*

21. Is this your first visit to a health centre because of this same illness?
Ese ni ubwa mbere ugannye ikigonderabuzima kubera ubu burwayi?

☐ yes/*Yego* ☐ no/*Oya*

22a. Have you visited a health centre during the past 3 months?/*Ese waba waragannye ikigonderabuzima mu gihe cy'amezi atatu ashize?*

☐ yes/*Yego* names of hc / *Amazina y'ikigonderabuzima*:

_____

_____

_____

☐ no/*Oya* When did you visit a hc for the last time?/*ni ryari uheruka kugana ikigonderabuzima*? _____

name of hc / *imazina y'ikigonderabuzima*:

_____

22b. How many times have you been to a health centre because of this same illness ***before*** today?/
ni incuro zingahe waba waragannye ikigonderabuzima kubera ubu burwayi mbere y'uyu munsi?

_____

22c. In which health centre(s) have you been before?
Ni ikihe kigonderabuzima waba waragannye mbere?

☐ here (the same health centre)/ *hano (kuri iki kigonderabuzima)*

☐ somewhere else/ *ahandi*:

names of hc (Sector/District)/ *Amazina y'ibigonderabuzima (Umurenge/Akarere)*:

_____

_____

_____

23. How would you rank this health centre compared to the neighbouring ones?/
Icyi kigo nderabuzima wagishyira ku mwanya wakangahe ugereranyije n'ibindi muturanye?

1. _____
2. _____
3. _____
4. _____
5. _____

24. How true are the following statements regarding your decision for coming to this health centre today?
Ni kukihe kigero wemeranya n'izi nterururo?

	Very true of me/ *Ni ukuri cyane*	True of me/ *Ni ukuri*	Neutral/ *Ndifashe*	Untrue of me/ *Si ukuri*	Very untrue of me/ *Si ukuri na buhoro*
a) This is the only health centre I know. / *Iri niryo vuriro nzi.*					
b) This is the nearest health centre. / *Iki nicyo kigonderabuzima kiri hafi*.					
c) This is the health centre with the best access by public transport. / *Iri niryo vuriro umuntu abona imodoka yo kujyayo ku buryo bworoshye.*					
d) This is the health centre which I can access the **quickest** way. / *Iri niryo vuriro riri hafi yanjye*.					
e) This is the health centre which I can access the most **comfortable** way./*Iri niryo vuriro nkunda.*					
f) This is the health centre which I can access the most **affordable** way./*Iri niryo vuriro rihendutse.*					
g) I know about the good service here. / *Hano mbaziho gutanga serivisi nziza*.					
h) I have been here before./*Nari ndi hano ubushize*.					
i) People are friendly. / *Abantu bafite urugwiro*.					
j) It was recommended. /*Barabitsabye*.					
k) They have electricity. / *Hari amashanyarazi*.					
l) They have water. / *Hari amazi*.					
m) I want to visit family members or friends on the way. / *Ndashaka gusura abo mumuryango mu nzira.*					
n) There is a market in this area today. / *Habaye isoko uyu munsi.*					
o) other reason / *indi mpamvu*: _____					

General information

This interview was done in ☐ Kinyarwanda ☐ English

by (name of interviewer) _____

Date _____ Time _____

Health Centre (Name/Sector/District): _____

_____

Further comments: _____

_____

_____

_____

Appendix B: Informed consent of patients

(see next page)

Dear patient,

This research is done on behalf of a German PhD student in the field of Geography. It aims to improve the accessibility of health care for the population. We therefore want to ask you some questions about your personal experience in the utilization of health centres. Your participation in this survey is voluntary but highly appreciated. You can choose not to answer any individual question or all of the questions. Refusing the participation or the answer of single questions will not have any consequences for you. If you want to participate, please answer the questions sincerely. The participation does not result in any payment.

Whatever information you provide will be stored anonymously and will only be used for this study. All data will be kept strictly confidential and will not be given or shown to anybody but the survey team.

At this time, do you want to ask me anything about the survey?

Nshuti murwayi,

Ubu bushakashatsi burakorwa mu rwego rw'amasomo y'icyiciro gihanitse cya Kaminuza mu ishami ry'ubumenyi bw'isi. Bugamije kongera uburyo abaturage bagezwaho ubufasha mu buvuzi. Ni muri urwo rwego dushaka kukubaza ibibazo bimwe na bimwe bijyanye n'ubunararibonye bwawe kugiti cyawe, mu gukoresha ibigonderabuzima. Ubufatanye bwawe muri ubu bushakashatsi ni ubushake bwawe ariko ni iby'agaciro gakomeye. Ni uburenganzira bwawe Kwanga ubufatanye cyangwa kwanga gusubiza kimwe mu bibazo cyane ko nta ngaruka iyo ariyo yose bishobora kukugiraho. Mu gihe wemeye ubufatanye, turakwinginze usubizanye ubunyangamugayo. Wemerewe kandi kudasubiza ikibazo runaka igihe utabiskaka. Ubufatanye ni ubwitange nta kindi gihembo giteganyijwemo.

Amakuru yose watanze azabikwa hatavuzwe nyir'ukuyatanga kandi azakoreshwa gusa muri ubu bushakashatsi ntazigera ahabwa undi uwo ariwe wese utari mu ikipi y'abashakashatsi.

Waba hari ikibazo wifuza kubaza ?

Date: _____ Health Centre: _____

Name of the patient	**Origin**	**Signature/thumb print**

Appendix C: Agreement of confidentiality signed by students

Agreement

I, _____ ,

Student's name

herewith undertake to treat all information and collected data in context of the study "Spatial disparities in the utilisation of health facilities in Huye District (Rwanda)" confidentially.
I undertake to follow the procedures at the enrolment of the survey at health facilities as informed during the training and the pre-test.

Huye, _____

Date, Signature

Appendix II: Questionnaire at presentation of preliminary results

Health Center: _____

Your names: _____

Your position at the HC: _____

Since when working at this HC? _____

Phone number (voluntary): _____

E-mail address (voluntary): _____

Please answer following questions as detailed as possible. Please keep in mind that the study took place in 2010.

Have you been aware of the catchment area presented for your health center (either that it is limited to the administrative boundary or the utilization from other sectors/districts, resp.)?

_____

_____

What do you <u>know</u> about reasons for this limited/expanded utilization?

_____

_____

_____

Which reasons can you imagine?

_____

_____

Did you experience a change in utilization during the last three years? Which kind of? Do you know reasons?

_____

_____

_____

Your comments:

_____

_____

_____

_____

_____

_____

_____

_____

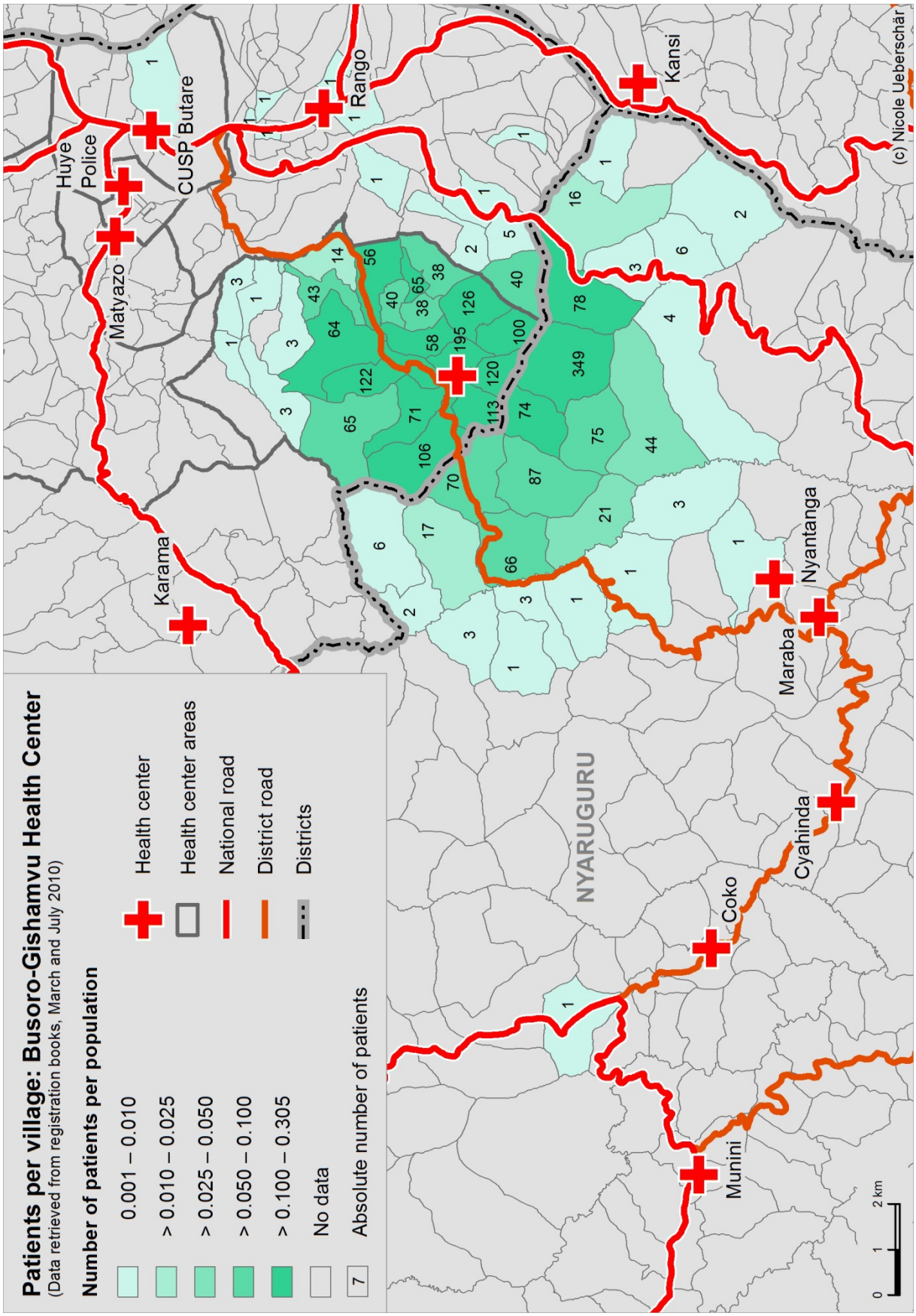
_____

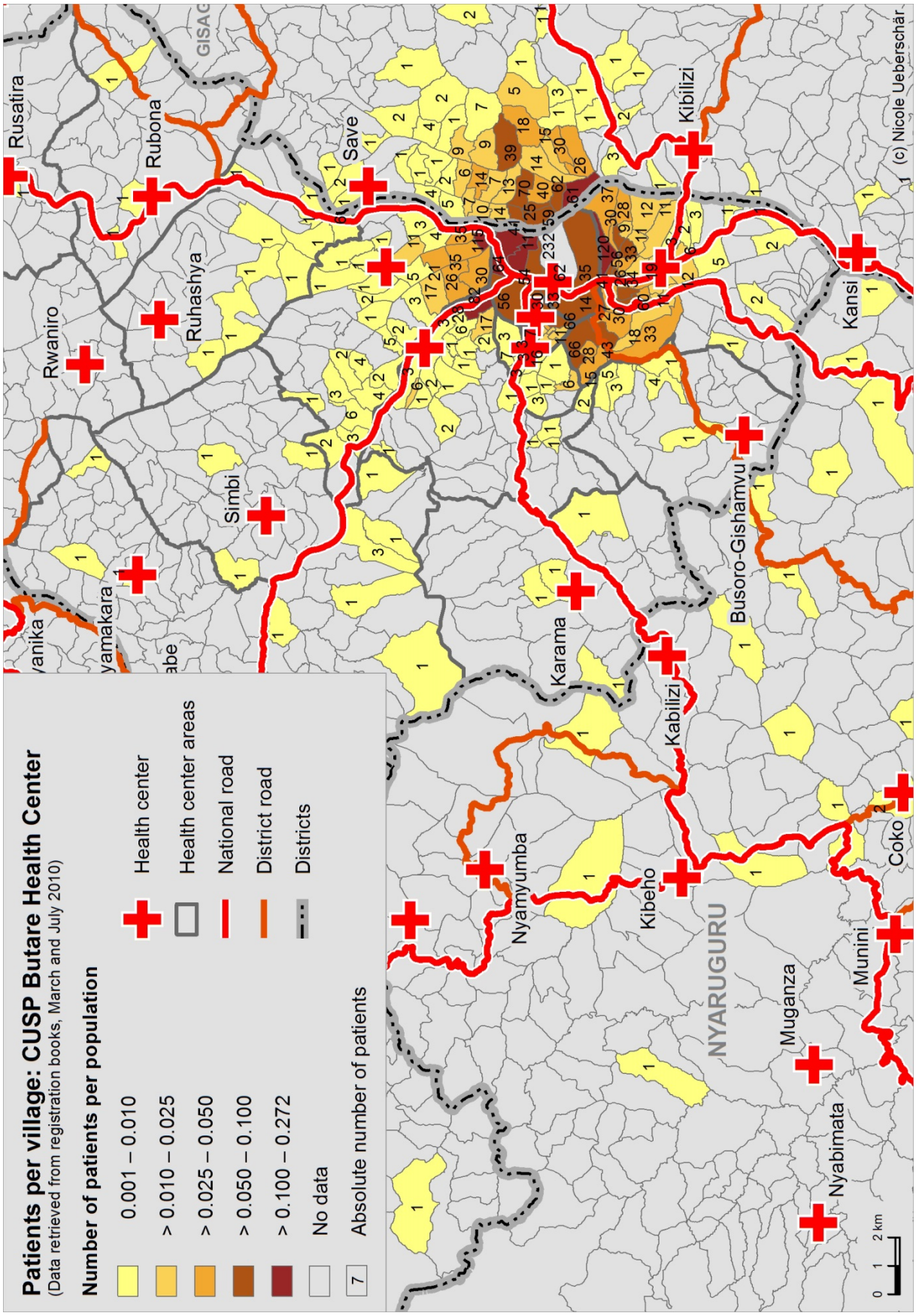
_____

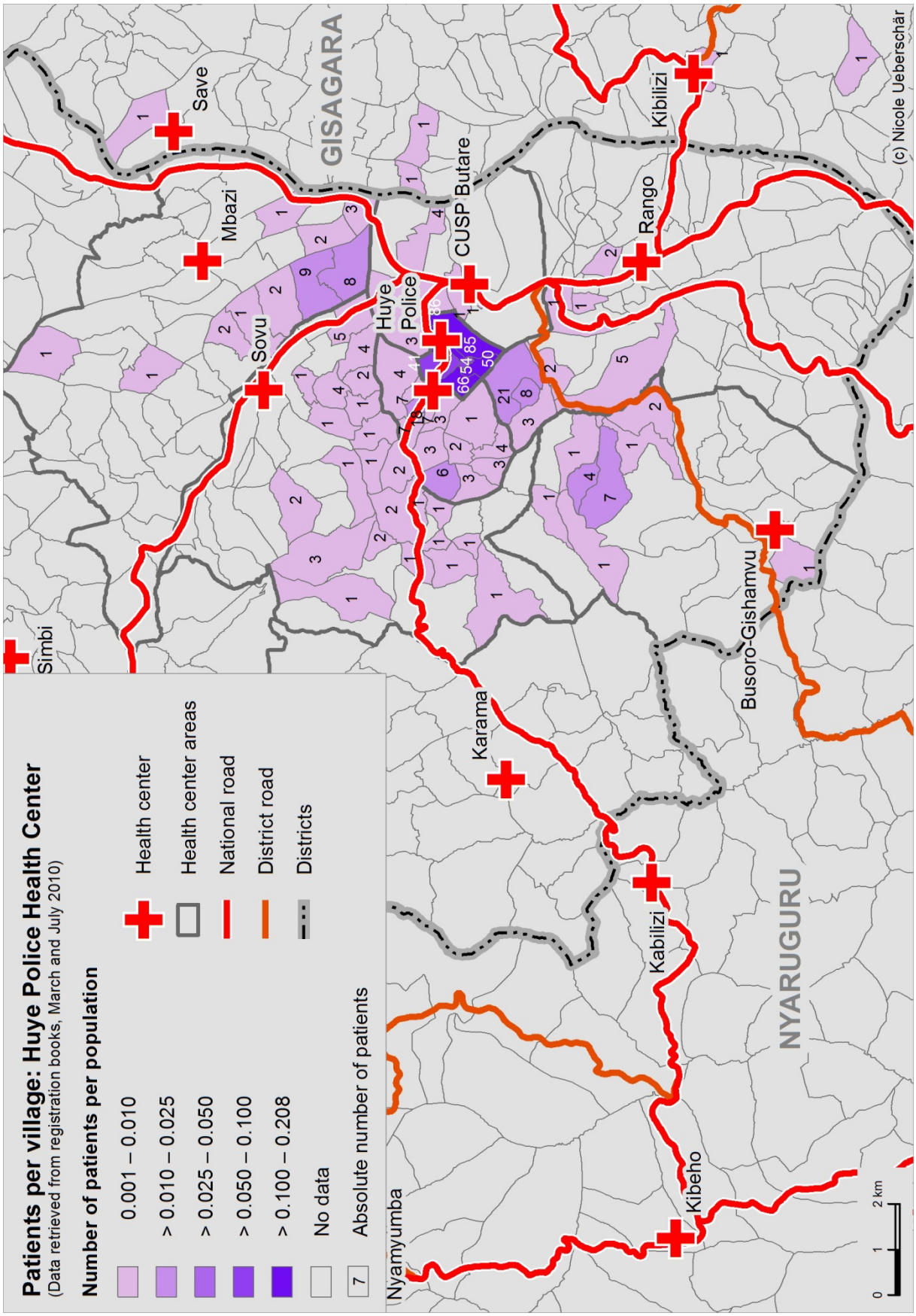
_____

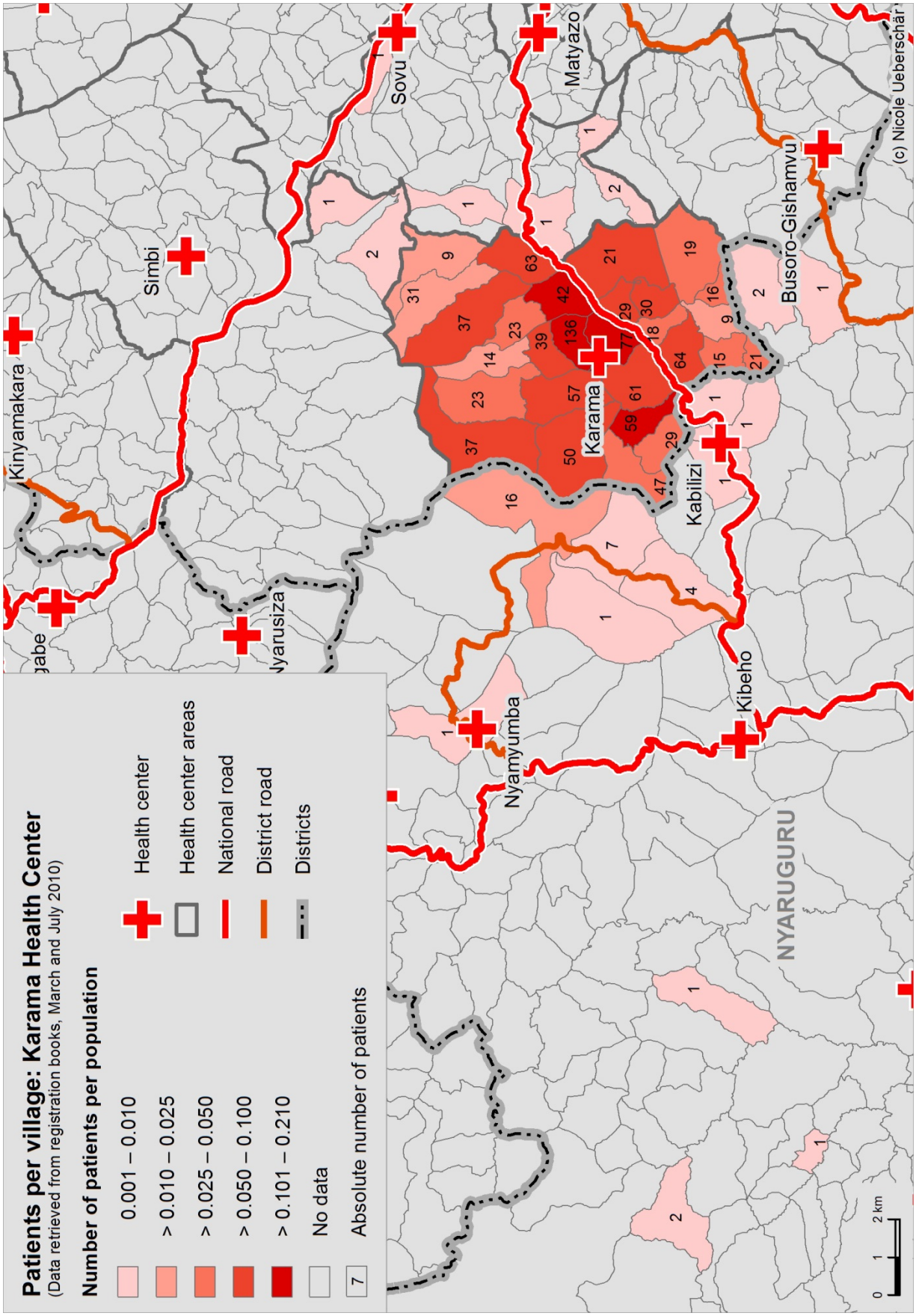
Thank you!

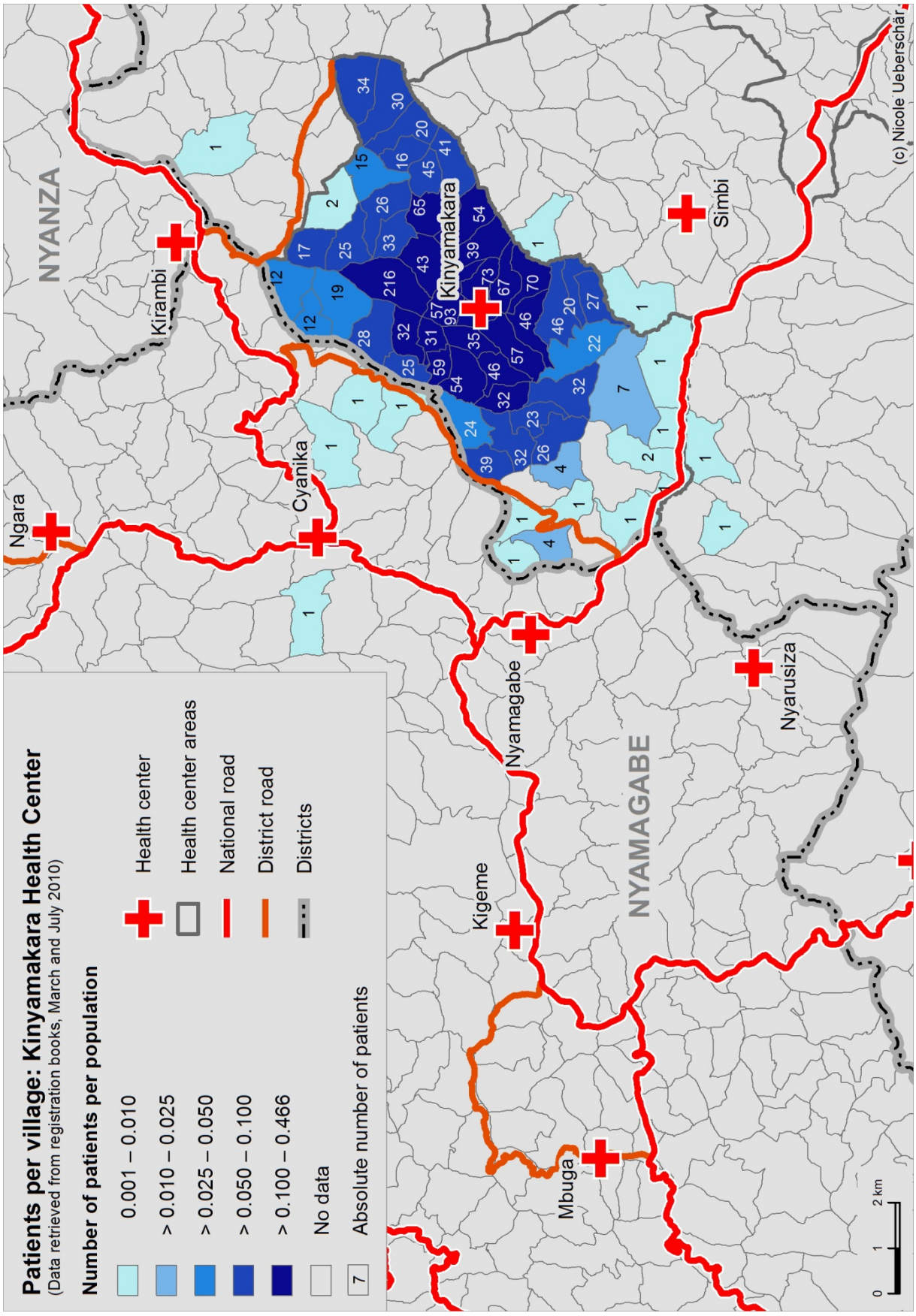
Appendix III: Detailed maps of utilization for all health centers in alphabetic order

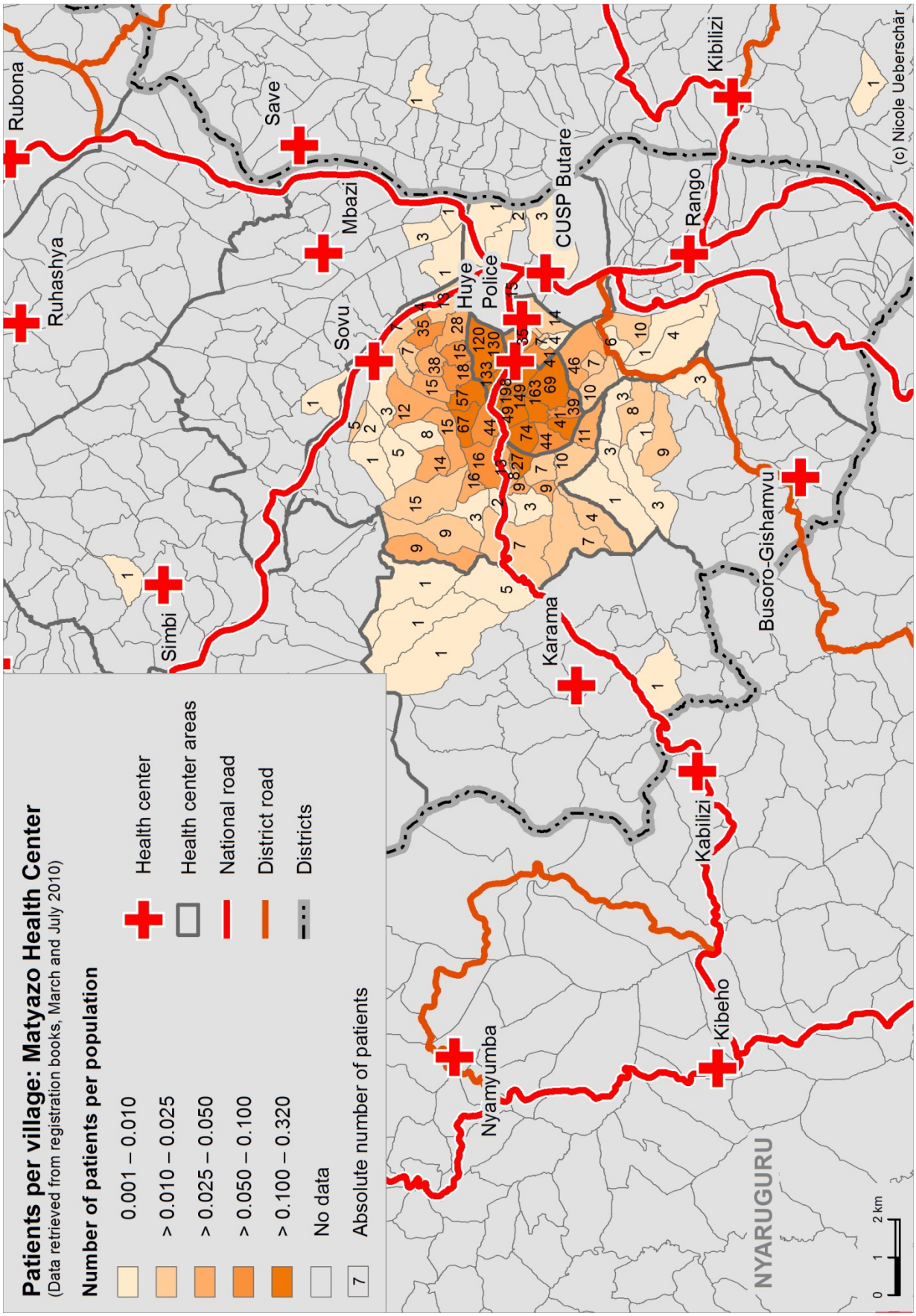

Patients per village: Busoro-Gishamvu Health Center
(Data retrieved from registration books, March and July 2010)
Number of patients per population
0.001 – 0.010
> 0.010 – 0.025
> 0.025 – 0.050
> 0.050 – 0.100
> 0.100 – 0.305
No data
Absolute number of patients
Health center
Health center areas
National road
District road
Districts
Huye
Police
Matyazo
CUSP Butare
Rango
Kansi
Karama
Maraba
Nyantanga
NYARUGURU
Coko
Cyahinda
Munini
0
1
2 km
(c) Nicole Ueberschär

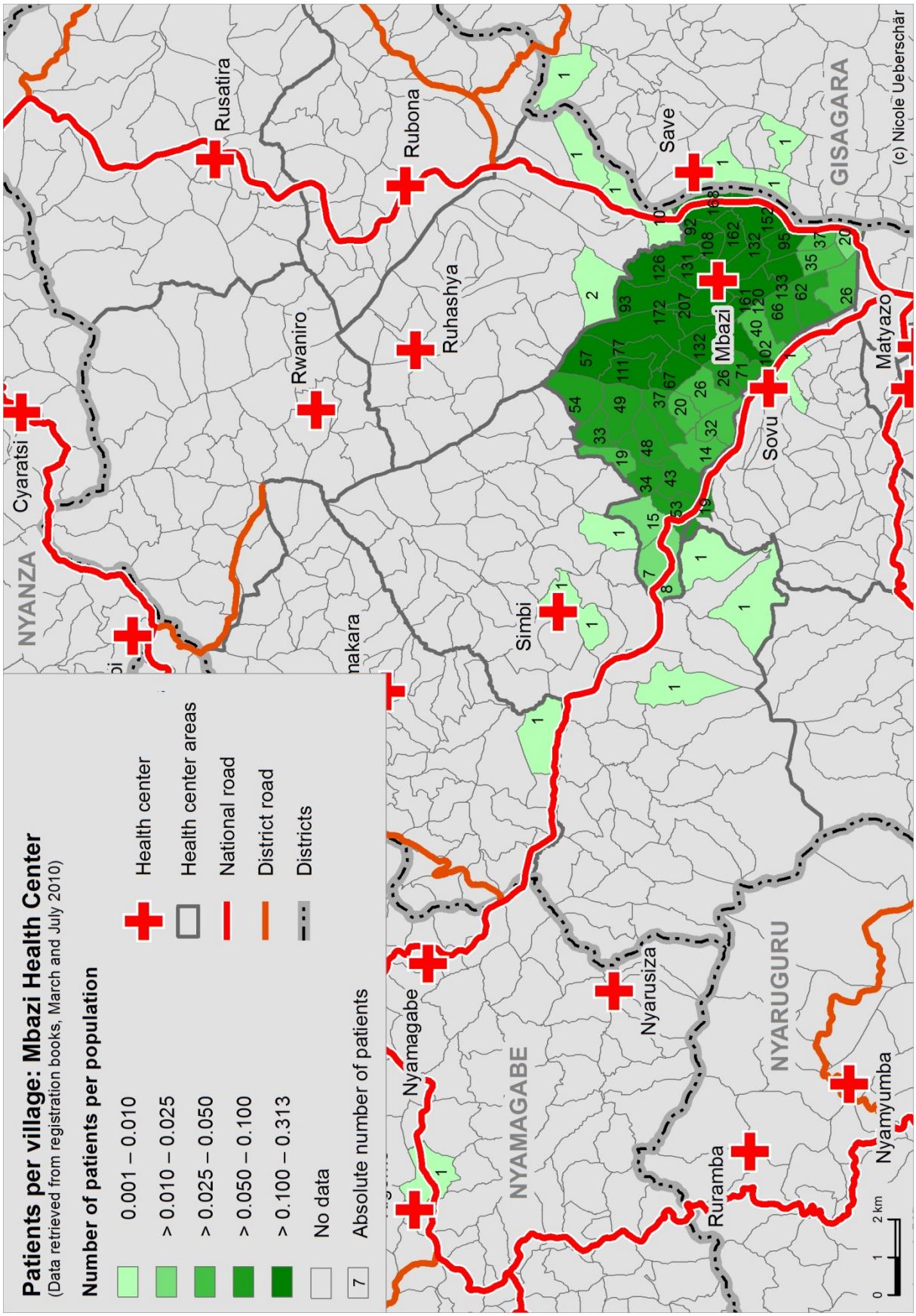

Patients per village: CUSP Butare Health Center
(Data retrieved from registration books, March and July 2010)
Number of patients per population
0.001 – 0.010
> 0.010 – 0.025
> 0.025 – 0.050
> 0.050 – 0.100
> 0.100 – 0.272
No data
Absolute number of patients
7
Health center
Health center areas
National road
District road
Districts
Rusatira
Rubona
Rwaniro
Ruhashya
Simbi
Save
Karama
Kabilizi
Kibilizi
Busoro-Gishamvu
Kansi
Nyamyumba
Kibeho
NYARUGURU
Muganza
Munini
Coko
Nyabimata
0 1 2 km
(c) Nicole Ueberschär

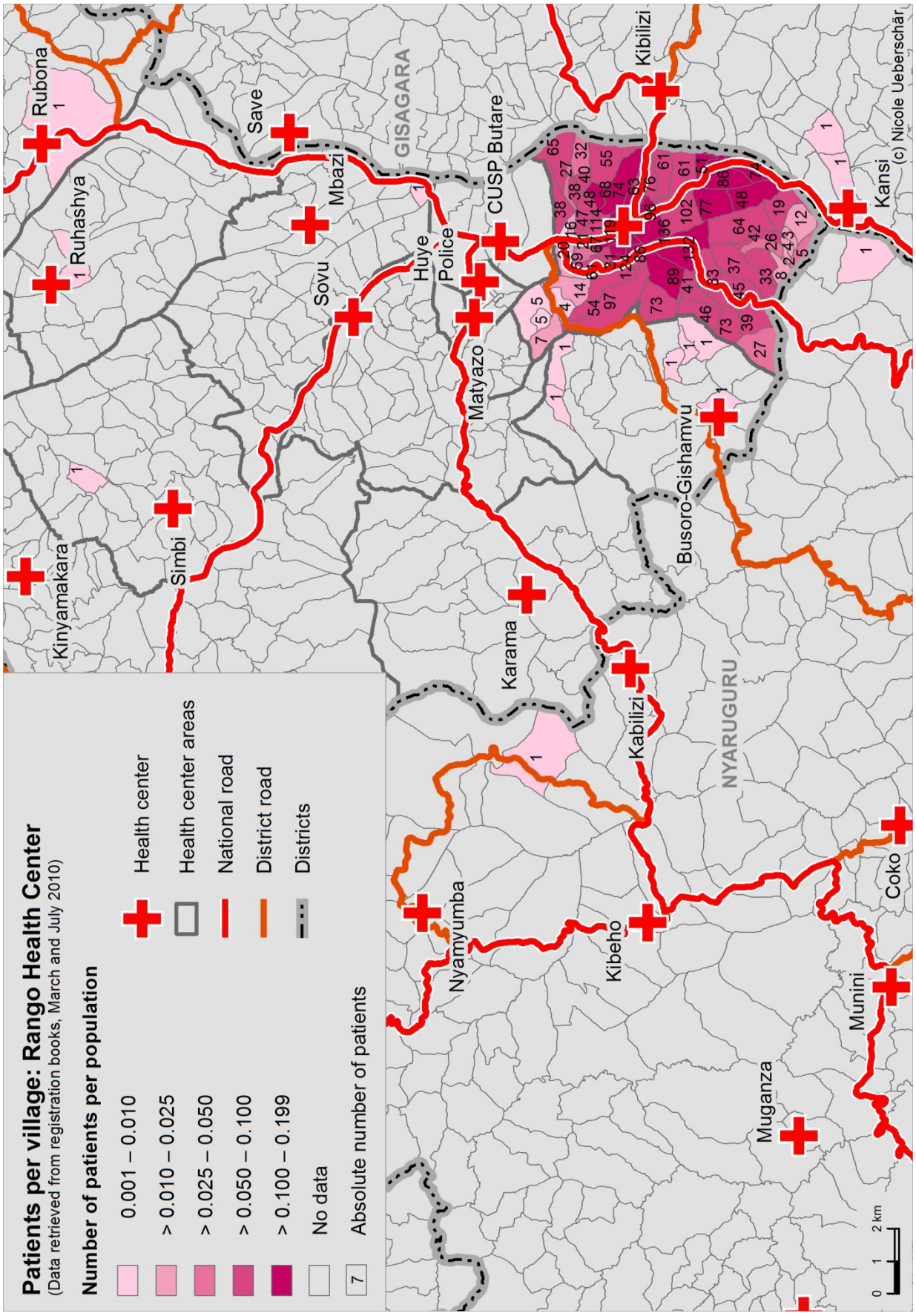

Patients per village: Huye Police Health Center
(Data retrieved from registration books, March and July 2010)
Number of patients per population
0.001 – 0.010
> 0.010 – 0.025
> 0.025 – 0.050
> 0.050 – 0.100
> 0.100 – 0.208
No data
Absolute number of patients
Health center
Health center areas
National road
District road
Districts
Simbi
Save
Mbazi
Sovu
GISAGARA
Huye
Police
CUSP Butare
Rango
Kibilizi
Karama
Busoro-Gishamvu
Kabilizi
NYARUGURU
Nyamyumba
Kibeho
0
1
2 km
(c) Nicole Ueberschär

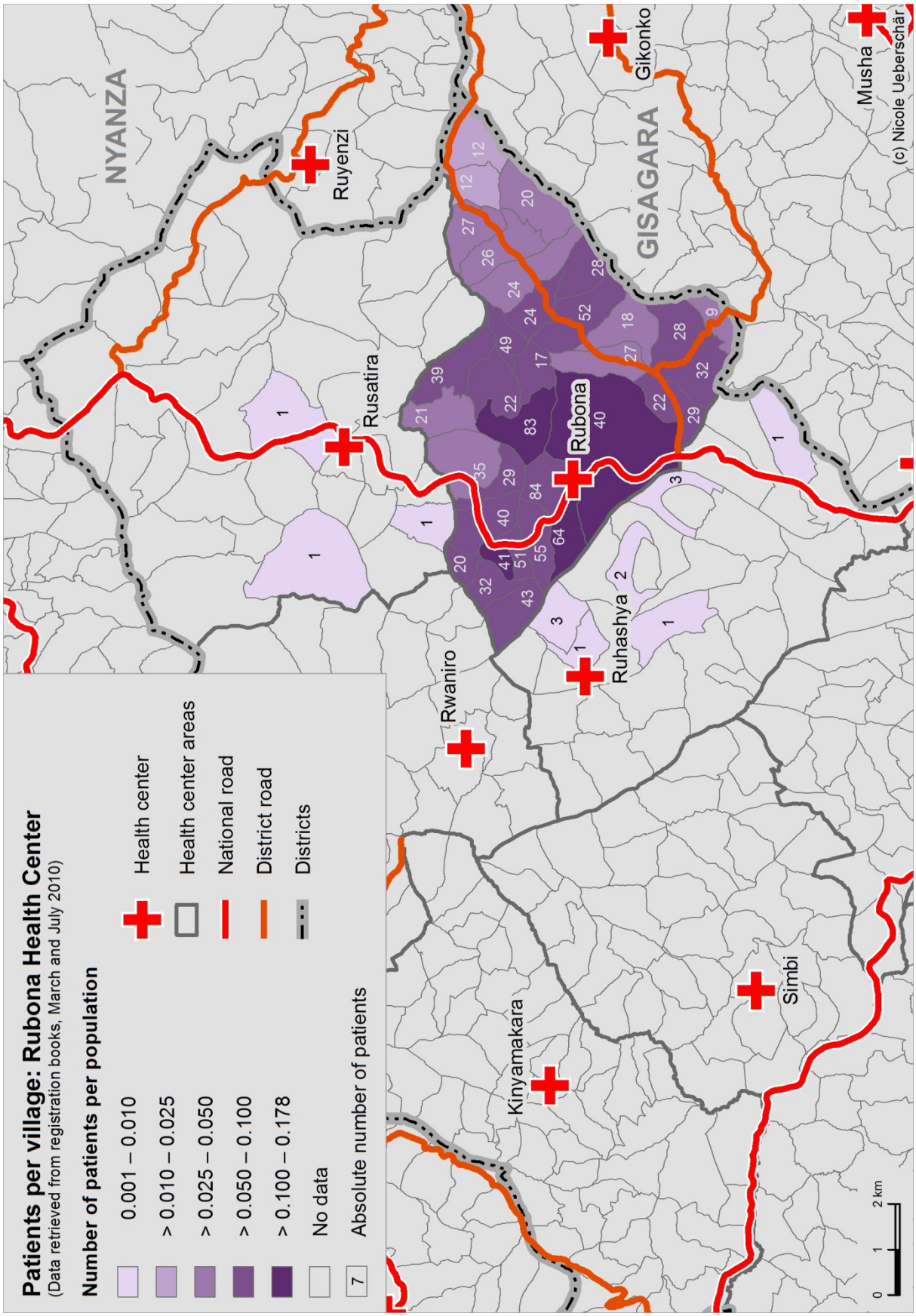

Patients per village: Karama Health Center
(Data retrieved from registration books, March and July 2010)
Number of patients per population
0.001 – 0.010
> 0.010 – 0.025
> 0.025 – 0.050
> 0.050 – 0.100
> 0.101 – 0.210
No data
7 Absolute number of patients
Health center
Health center areas
National road
District road
Districts
Kinyamakara
Simbi
Sovu
Matyazo
Busoro-Gishamvu
Karama
Kabilizi
Kibeho
Nyamyumba
NYARUGURU
0 1 2 km
(c) Nicole Ueberschär

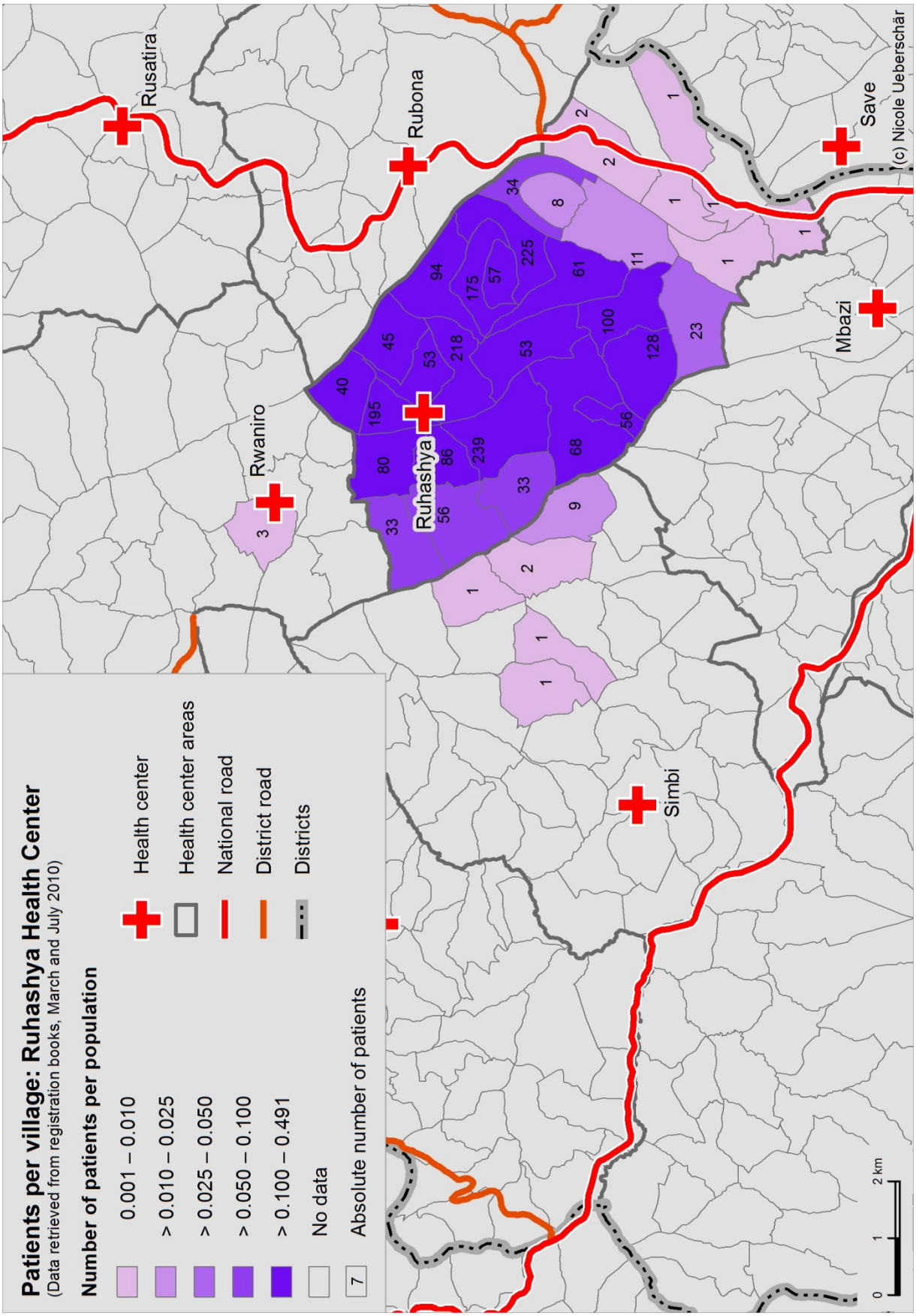

Patients per village: Kinyamakara Health Center
(Data retrieved from registration books, March and July 2010)
Number of patients per population
0.001 – 0.010
> 0.010 – 0.025
> 0.025 – 0.050
> 0.050 – 0.100
> 0.100 – 0.466
No data
7 Absolute number of patients
Health center
Health center areas
National road
District road
Districts
NYANZA
NYAMAGABE
Kinyamakara
Kirambi
Ngara
Cyanika
Nyamagabe
Kigeme
Mbuga
Nyarusiza
Simbi
0 1 2 km
(c) Nicole Ueberschär

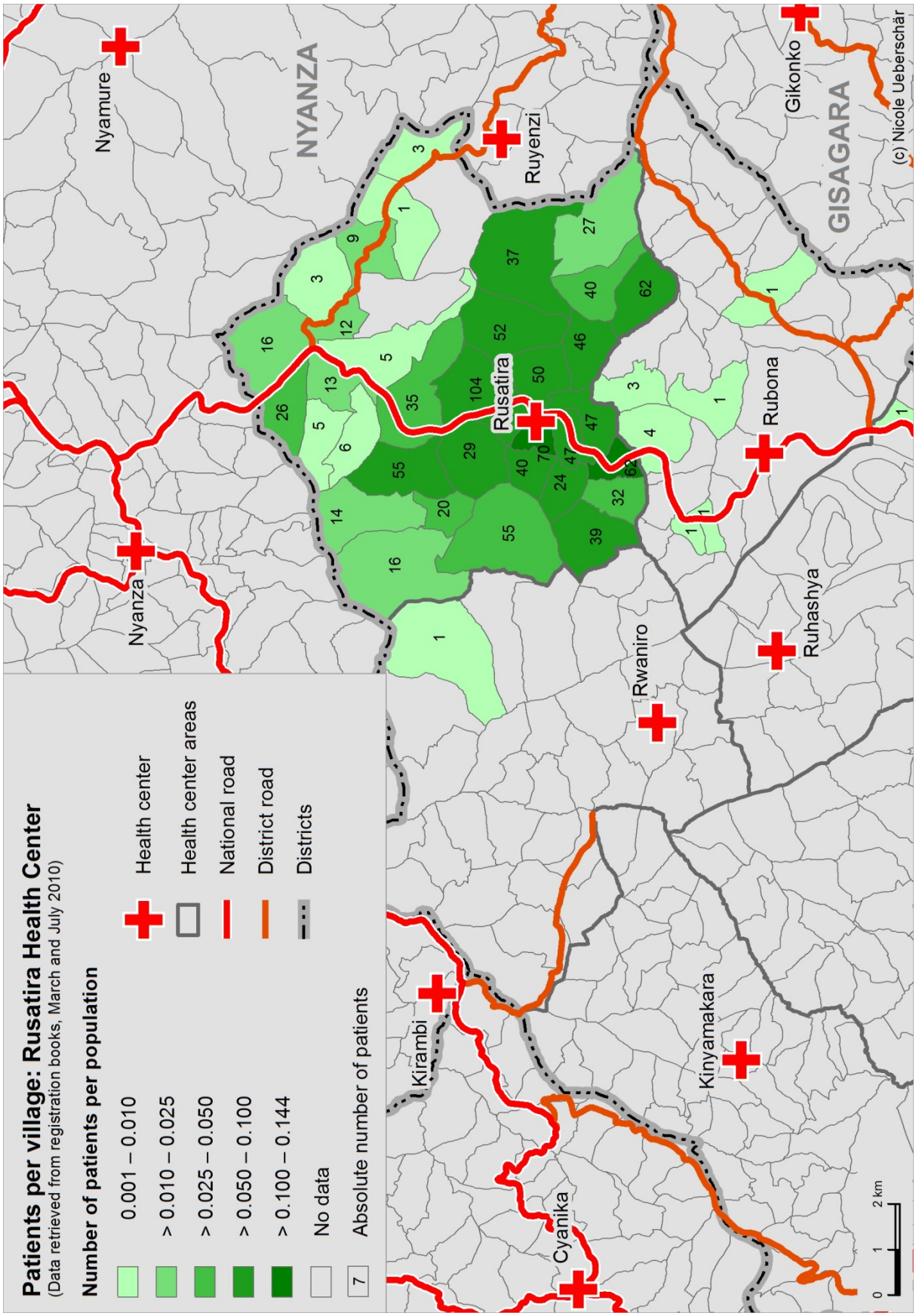

Patients per village: Matyazo Health Center
(Data retrieved from registration books, March and July 2010)
Number of patients per population
0.001 – 0.010
> 0.010 – 0.025
> 0.025 – 0.050
> 0.050 – 0.100
> 0.100 – 0.320
No data
7 Absolute number of patients
Health center
Health center areas
National road
District road
Districts
Rubona
Ruhashya
Save
Mbazi
Sovu
Huye
Police
CUSP Butare
Rango
Kibilizi
Simbi
Karama
Busoro-Gishamvu
Kabilizi
Nyamyumba
Kibeho
NYARUGURU
0 1 2 km
(c) Nicole Ueberschär

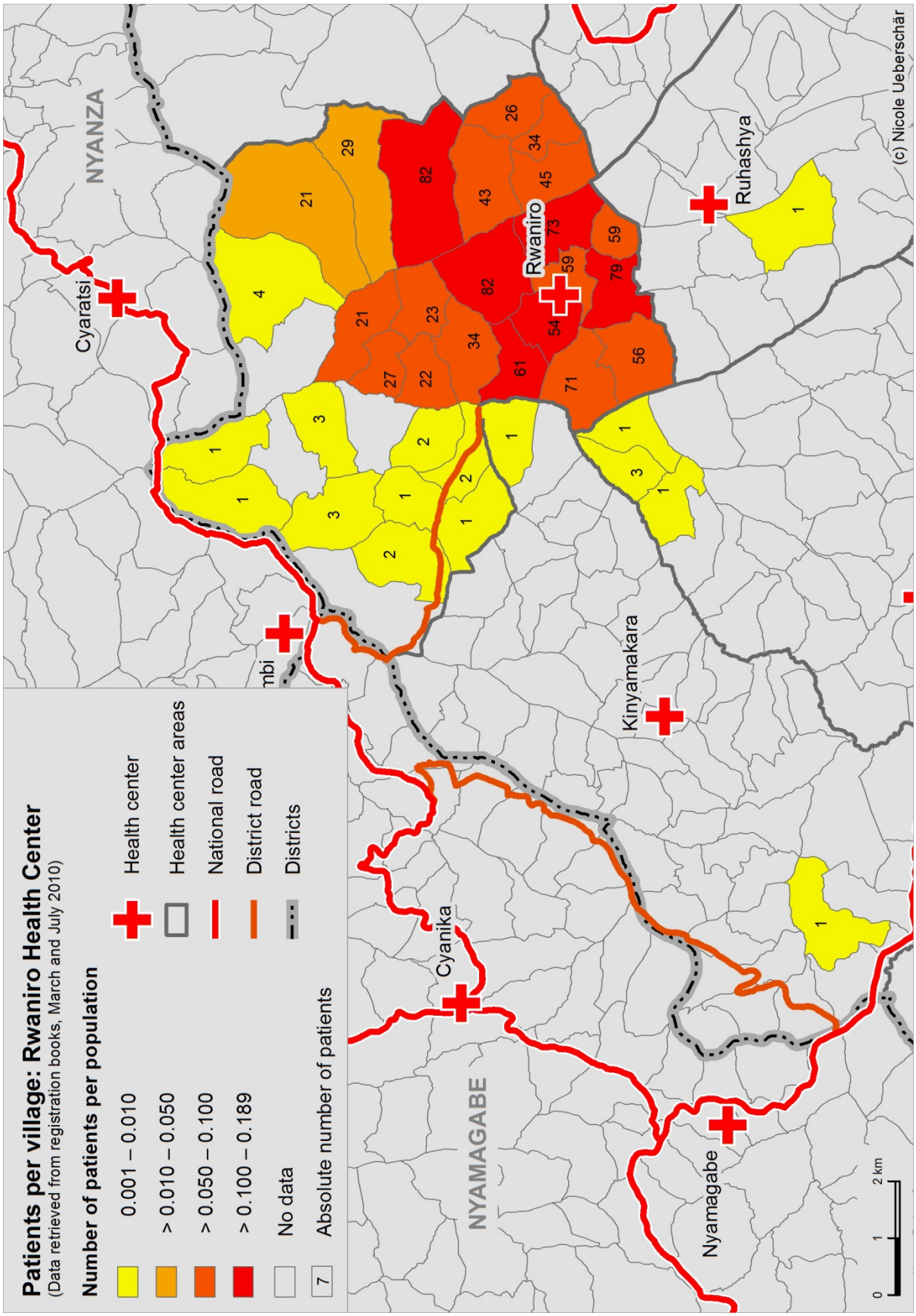

Patients per village: Mbazi Health Center
(Data retrieved from registration books, March and July 2010)
Number of patients per population
0.001 – 0.010
> 0.010 – 0.025
> 0.025 – 0.050
> 0.050 – 0.100
> 0.100 – 0.313
No data
Absolute number of patients
7
Health center
Health center areas
National road
District road
Districts
NYANZA
Cyaratsi
Rusatira
Rwaniro
Rubona
Ruhashya
Simbi
Save
Mbazi
Sovu
Matyazo
GISAGARA
NYAMAGABE
Nyamagabe
Nyarusiza
Ruramba
NYARUGURU
Nyamyumba
0 1 2 km
(c) Nicole Ueberschär

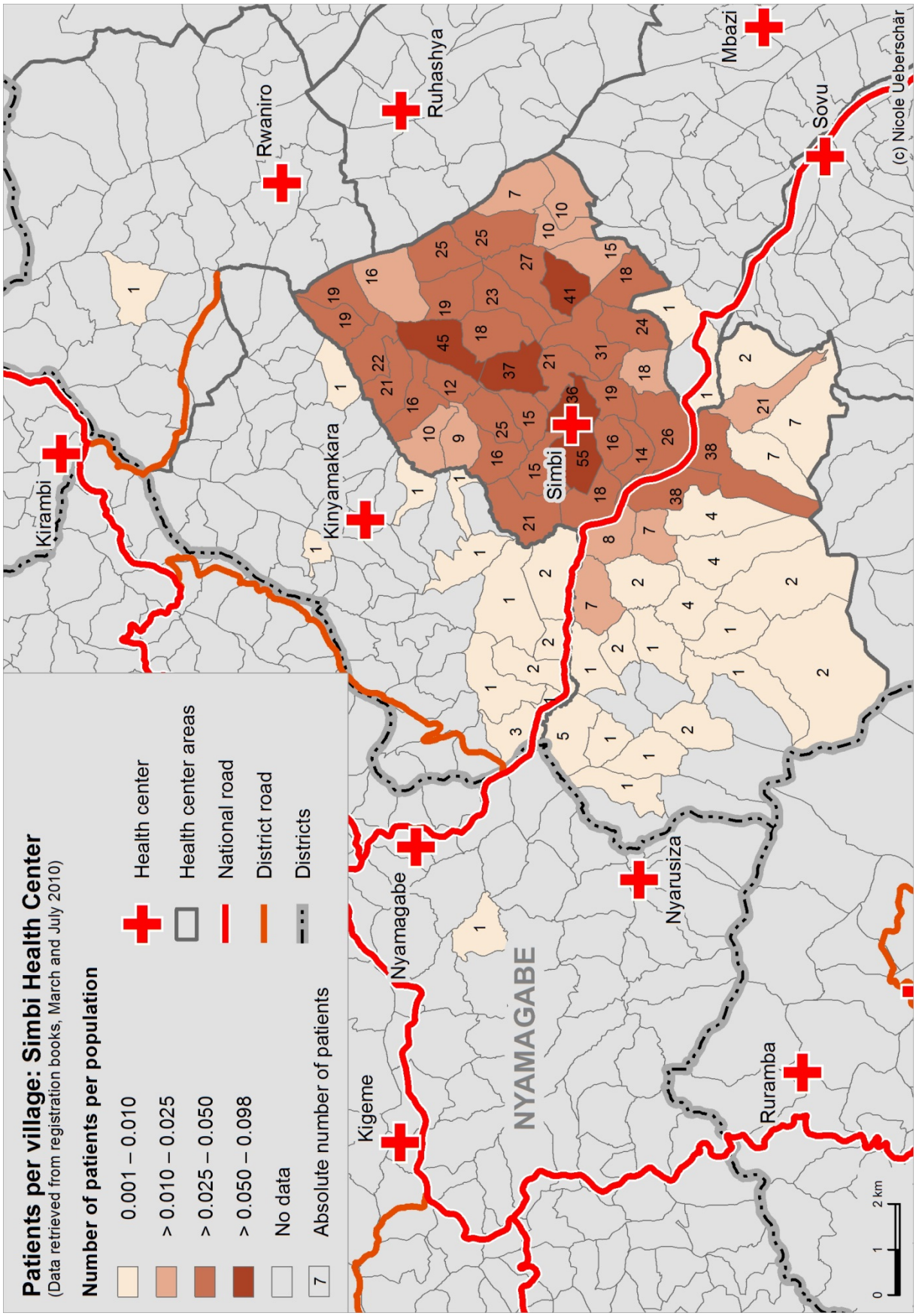

Patients per village: Rango Health Center
(Data retrieved from registration books, March and July 2010)
Number of patients per population
0.001 – 0.010
> 0.010 – 0.025
> 0.025 – 0.050
> 0.050 – 0.100
> 0.100 – 0.199
No data
Absolute number of patients
7
Health center
Health center areas
National road
District road
Districts
Rubona
Ruhashya
Kinyamakara
Simbi
Save
Mbazi
Sovu
Huye
Police
GISAGARA
CUSP Butare
Matyazo
Karama
Kabilizi
Kibilizi
Busoro-Gishamvu
NYARUGURU
Nyamyumba
Kibeho
Muganza
Munini
Coko
Kansi
(c) Nicole Ueberschär
0 1 2 km

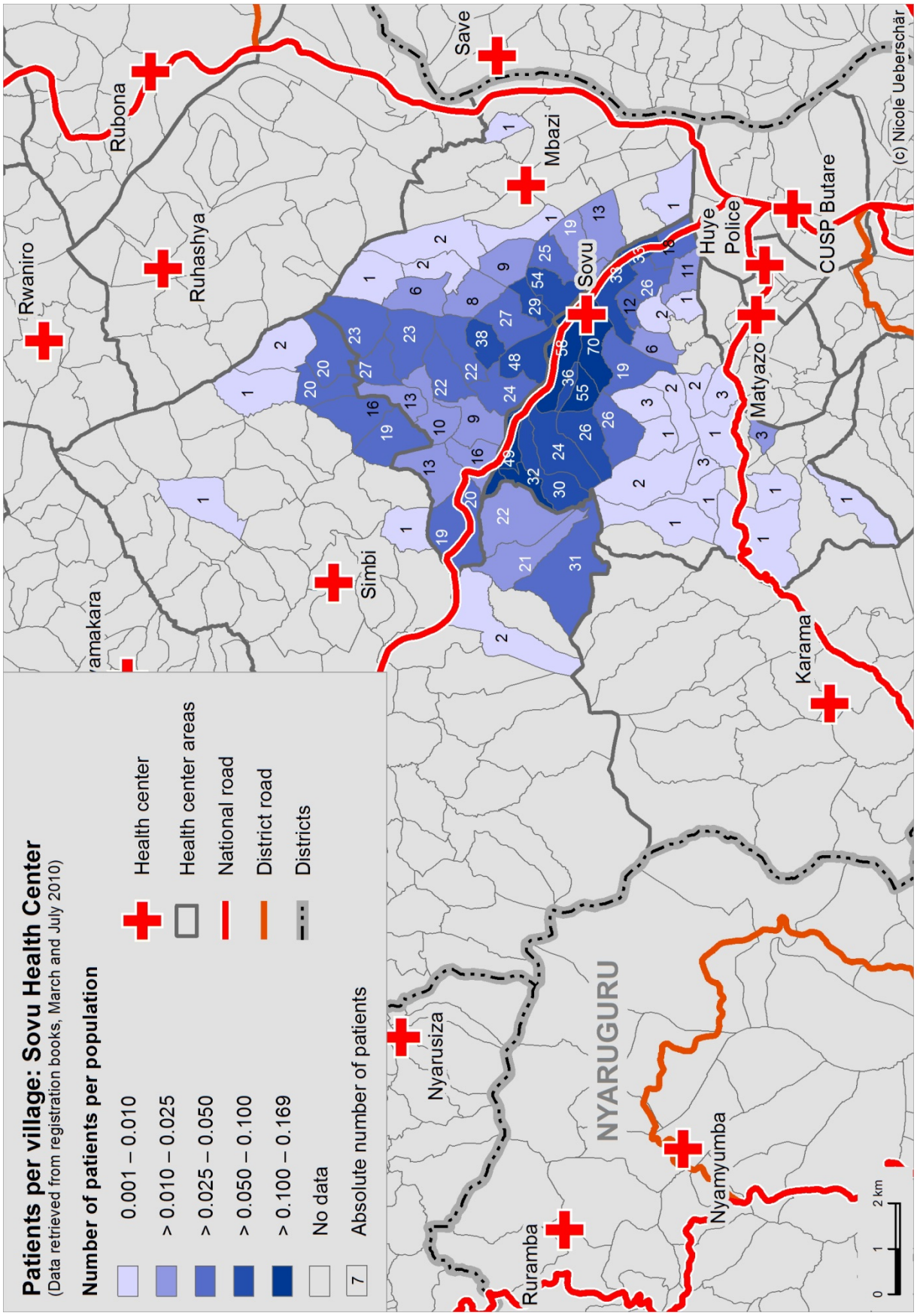

Patients per village: Rubona Health Center
(Data retrieved from registration books, March and July 2010)
Number of patients per population
0.001 – 0.010
> 0.010 – 0.025
> 0.025 – 0.050
> 0.050 – 0.100
> 0.100 – 0.178
No data
Absolute number of patients
Health center
Health center areas
National road
District road
Districts
NYANZA
GISAGARA
Ruyenzi
Rusatira
Rubona
Gikonko
Musha
Rwaniro
Ruhashya
Kinyamakara
Simbi
0 1 2 km
(c) Nicole Ueberschär


Patients per village: Ruhashya Health Center
(Data retrieved from registration books, March and July 2010)
Number of patients per population
0.001 – 0.010
> 0.010 – 0.025
> 0.025 – 0.050
> 0.050 – 0.100
> 0.100 – 0.491
No data
7 Absolute number of patients
Health center
Health center areas
National road
District road
Districts
Rusatira
Rubona
Save
Rwaniro
Ruhashya
Mbazi
Simbi
0
1
2 km
(c) Nicole Ueberschär


Patients per village: Rusatira Health Center
(Data retrieved from registration books, March and July 2010)
Number of patients per population
0.001 – 0.010
> 0.010 – 0.025
> 0.025 – 0.050
> 0.050 – 0.100
> 0.100 – 0.144
No data
Absolute number of patients
Health center
Health center areas
National road
District road
Districts
NYANZA
GISAGARA
Nyamure
Nyanza
Kirambi
Cyanika
Rwaniro
Kinyamakara
Ruyenzi
Rusatira
Rubona
Ruhashya
Gikonko
0 1 2 km
(c) Nicole Ueberschär


Patients per village: Rwaniro Health Center
(Data retrieved from registration books, March and July 2010)
Number of patients per population
0.001 – 0.010
> 0.010 – 0.050
> 0.050 – 0.100
> 0.100 – 0.189
No data
Absolute number of patients
Health center
Health center areas
National road
District road
Districts
NYANZA
NYAMAGABE
Cyaratsi
Rwaniro
Ruhashya
Kinyamakara
Cyanika
Nyamagabe
0
1
2 km
(c) Nicole Ueberschär


Patients per village: Simbi Health Center
(Data retrieved from registration books, March and July 2010)
Number of patients per population
0.001 – 0.010
> 0.010 – 0.025
> 0.025 – 0.050
> 0.050 – 0.098
No data
Health center
Health center areas
National road
District road
Districts
Absolute number of patients
Kirambi
Rwaniro
Ruhashya
Mbazi
Sovu
Kinyamakara
Simbi
Nyamagabe
Nyarusiza
Kigeme
Ruramba
NYAMAGABE
0
1
2 km
(c) Nicole Ueberschär


Patients per village: Sovu Health Center
(Data retrieved from registration books, March and July 2010)
Number of patients per population
0.001 – 0.010
> 0.010 – 0.025
> 0.025 – 0.050
> 0.050 – 0.100
> 0.100 – 0.169
No data
Absolute number of patients
7
Health center
Health center areas
National road
District road
Districts
Rubona
Ruhashya
Rwaniro
Save
Mbazi
Sovu
Huye
Police
CUSP Butare
Matyazo
Karama
Simbi
Nyarusiza
NYARUGURU
Nyamyumba
Ruramba
0
1
2 km
(c) Nicole Ueberschär